Wildlife Surveillance Concept Human-in-the-Loop Laboratory Demonstration

October 2016

DOT/FAA/TC-TN16/45

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/TC-TN16/45		

4. Title and Subtitle	5. Report Date
WILDLIFE SURVEILLANCE CONCEPT HUMAN-IN-THE-LOOP LABORATORY DEMONSTRATION	October 2016
	6. Performing Organization Code
7. Author(s) Mark R. Hale* and Anton Koros	8. Performing Organization Report No.
9. Performing Organization Name and Address U. S. Department of Transportation Federal Aviation Administration Airport Safety R&D Section William J. Hughes Technical Center Atlantic City International Airport, NJ 08405 *CSSI, Inc. 425 3rd Street, SW, Suite 700 Washington, DC 20024	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address U. S. Department of Transportation Federal Aviation Administration William J. Hughes Technical Center Airport Safety R&D Section Atlantic City International Airport, NJ 08405	13. Type of Report and Period Covered Technical Note
	14. Sponsoring Agency Code ANG-E261

15. Supplementary Notes

This project was conducted under the terms of a Service Level Agreement between the Airport Safety Research and Development Section and the Advanced Concept Development and Validation Branch. The COR for this project was Ryan King.

16. Abstract

This report evaluates alternative methods for introducing enhanced bird threat information into the Air Traffic Control (ATC) environment. It is part of a larger multifaceted Federal Aviation Administration (FAA) effort to reduce significant bird strikes at civil airports nationwide. The FAA Airport Safety Research and Development Section sponsored the Advanced Concept Development and Validation Branch to develop and mature a concept to provide near real-time bird threat information directly to ATC personnel in the Airport Traffic Control Tower (ATCT). Specifically, the Wildlife Surveillance Concept (WiSC) Human-in-the-Loop Laboratory Demonstration focused on evaluating several notional display options for presenting this enhanced information to Certified Professional Controllers (CPCs) in the ATCT environment.

Six CPCs from ATCT facilities traveled to the William J. Hughes Technical Center Research Development Human Factors Laboratory (RDHFL) to participate in this simulation study over the course of 2 weeks in March 2015. Participants were recruited from among the facilities with the most significant bird strike incidents as identified in the FAA National Wildlife Strike Database. The simulation took place in the RDHFL's ATCT simulator. The simulation environment consisted of the Distributed Environment for Simulation, Rapid Engineering, and Experimentation ATC simulator and the Target Generator Facility. Scenarios were developed with representative Philadelphia International Airport operations and a simplified aircraft traffic mix and volume for use in the simulator.

A total of four research conditions were provided to each participant. Questionnaire data, over-the-shoulder supervisor ratings, and push-to-talk communications related to controller performance and preference using small-sample inferential statistical methods were analyzed. One of the key underlying themes observed regarding WiSC presentation preference was the tradeoff between information quality and the potential impact on workload. The WiSC target condition clearly provided the most accurate, complete, and useful bird threat information to controllers without significantly increasing workload over the baseline ratings. However, workload measures were lower in the WiSC text and WiSC supervisor conditions compared to the baseline and WiSC target condition.

17. Key Words	18. Distribution Statement
Avian radar, Birds, Human-in-the-loop, Simulation, Wildlife, Surveillance, Bird strikes, Wildlife Surveillance Concept	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	76	

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Ryan King of the Federal Aviation Administration (FAA) Airport Safety Research and Development Section for providing the vehicle for this research and for his guidance throughout the development and execution of this Wildlife Surveillance Concept (WiSC) Human-in-the-Loop Laboratory Demonstration.

The authors extend their appreciation to the support contractors who spent many hours working collaboratively with the authors, and who, through their technical expertise, contributed significantly to the success of this study. Specifically, the authors thank Mr. John Pallante (John Pallante and Associates) and Mr. John Kelley (John Pallante and Associates) for their hours of dedication as Airport Traffic Control Tower Subject Matter Experts.

The authors acknowledge the many contributions of the personnel at the Research Development Human Factors Laboratory. Specifically, Mr. Albert Macias (FAA) for his efforts in developing and managing WiSC laboratory requirements, and Mr. Adam Granich (Engility) for his efforts in developing the WiSC information displays. The authors also acknowledge Mr. Otto Smith (Engility), Mr. Wallace Daczkowski (Engility), and Mr. John Dilks (Engility) for their management of the laboratory infrastructure during this simulation study.

The authors recognize the significant contributions made by Dr. Ray Stanley (The MITRE Corporation) whose expertise in Human Factors Engineering was extremely valuable in the development and execution of this simulation study. Also, thanks to Ms. Elaine Morin (The MITRE Corporation) for her Air Traffic Control (ATC) input and analysis, as well as her many programmatic insights.

Special thanks to Mr. Charlie Baker (FAA) and Mr. Joe Calamita (FAA) for lending their ATC operational expertise at critical stages in this project. The authors also thank Ms. Kim Fitzpatrick for her efforts in planning and conducting this simulation study.

Last, the authors are grateful to the FAA management and ATC staff in Denver, Memphis, Orlando, and Salt Lake City for providing their support and volunteering to participate in this simulation study.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
ASDE-X	Airport Surface Detection Equipment - Model X
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATIS	Air Traffic Information Service
ATWIT	Air Traffic Workload Input Technique
BDX	Bird
CPC	Certified Professional Controller
DEN	Denver International Airport
DESIREE	Distributed Environment for Simulation, Rapid Engineering, & Experimentation
DFW	Dallas-Fort Worth International Airport
FAA	Federal Aviation Administration
HFS	Human factors specialist
HITL	Human-in-the-loop
IDS	Information Display System
LLWAS	Low Level Windshear Alert System
M	Mean
MCO	Orlando International Airport
MEM	Memphis International Airport
NAS	National Airspace System
ORF	Observer Rating Form
OTW	Out-the-window
PHL	Philadelphia International Airport
PIREPS	Pilot Reports
PSQ	Post Scenario Questionnaire
PTT	Push-to-talk
RDHFL	Research Development Human Factors Laboratory
SD	Standard deviation
SEA	Seattle Tacoma International Airport
SLC	Salt Lake City International Airport
SME	Subject matter expert
STARS	Standard Terminal Automation Replacement System
TGF	Target Generation Facility
VFR	Visual Flight Rules
WAK	Workload assessment keypad
WiSC	Wildlife Surveillance Concept

EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) recognizes the need to mitigate the growing threat of collisions between birds and aircraft. Reported bird strikes have increased more than six fold from 1990 to 2013 and cost an estimated $625 million annually to civil aviation in the United States. This technical note evaluates alternative methods for introducing enhanced bird threat information into the Air Traffic Control (ATC) environment. It is part of a larger multifaceted FAA effort to reduce significant bird strikes at civil airports nationwide.

The FAA Airport Safety Research and Development Section sponsored the Advanced Concept Development and Validation Branch to develop and mature a concept to provide near real-time bird threat information directly to ATC personnel in the Airport Traffic Control Tower (ATCT). Specifically, the Wildlife Surveillance Concept (WiSC) Human-in-the-Loop Laboratory Demonstration focused on evaluating several notional display options for presenting this enhanced information to Certified Professional Controllers (CPC) in the ATCT environment.

Six CPCs from ATCT facilities traveled to the William J. Hughes Technical Center Research Development Human Factors Laboratory (RDHFL) to participate in this simulation study over the course of 2 weeks in March 2015. Participants were recruited from among the facilities with the most significant bird strike incidents as identified in the FAA National Wildlife Strike Database. The simulation took place in the RDHFL's ATCT simulator. The simulation environment consisted of the Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) ATC simulator and the Target Generation Facility (TGF). DESIREE presented a realistic out-the-tower-cab-window representation of the Philadelphia International Airport (PHL) surface, while the TGF presented realistic aircraft movement during the simulation. Scenarios were developed with representative PHL operations and a simplified aircraft traffic mix and volume for use in the simulator. Realistic bird activity was developed and injected on the radar display and scripted simulation pilot interactions based on aircraft-bird proximity.

A total of four research conditions were presented to each participant. The baseline condition mirrored current ATC procedures. In the baseline condition, pilot reports served as the only source of bird threat information, and the participants were instructed to follow current procedures and protocols for the dissemination of bird threat information. The three experimental conditions were the WiSC target, WiSC text, and WiSC supervisor presentation methods. In the WiSC target condition, precise bird threat information was provided directly to the participant's primary radar display in the form of a bird symbol and information tag. The WiSC text condition consisted of bird threat information supplied in an abbreviated textbox format in the upper left of the controller's primary radar display. New and updated bird threat information triggered an aural alert in the WiSC text condition to draw the participant's attention to it. The WiSC supervisor condition contained the same abbreviated information found in the WiSC text condition but was handed to the participant by research team instead of being presented on the display.

Questionnaire data, over-the-shoulder supervisor ratings, and push-to-talk communications related to controller performance and preference using small-sample inferential statistical methods were analyzed. The analyses results indicated that participants considered WiSC to be a

major improvement over current methods of detecting and disseminating bird threat information, without introducing unnecessary complexity, workload, or bird-related voice communications. Participants were unanimously in favor of receiving more accurate and current bird threat information and considered the presentation methods demonstrated in the simulation to be a good first step.

Most participants favored the WiSC target presentation due to the precise position data that it provided. This allowed them to pass the most complete and accurate bird threat information to pilots. The WiSC text presentation was also rated very highly across all participants, with one participant preferring this method because of the ease of interpreting the bird threat information displayed. The WiSC supervisor presentation was least favored due to real-world implementation concerns, such as physical ATCT layout, supervisor workload, and shared responsibility for the management and dissemination of bird threat information.

Overall, the participants favored providing the WiSC information, whether in target or text format, on the tower primary radar display system. In the WiSC target condition, participants were unanimous in this preference. In the WiSC text condition, participants still favored the primary radar display, with alternative suggestions, such as the Information Display System and Low Level Windshear Alert System. Participants were in favor of the aural alert tone that was used to indicate new bird threat information in the WiSC text condition. Participants reported that the aural alert was a critical feature in the WiSC text condition and suggested incorporating an aural alert in the WiSC target condition.

One of the key underlying themes observed regarding the WiSC presentation preference was the tradeoff between information quality and the potential impact on workload. The WiSC target condition clearly provided the most accurate, complete, and useful bird threat information to controllers without significantly increasing workload over the baseline ratings. However, workload measures were lower in the WiSC text and WiSC supervisor conditions compared to the baseline and WiSC target condition.

During the debrief session, the participants offered a solution to offset the potential tradeoff between quality of information and controller workload. They suggested employing a hybrid target/text mode approach. The WiSC text format could be provided as the default presentation method to the controller. If a controller required additional detailed information, preferred this mode, or traffic levels were low, they could select the WiSC target format. In this way, controllers could choose to receive more precise information based on their preference, the operational need, and current conditions.

The concept and technology encompassed by WiSC offers promise and could be matured through field and simulation activities. The authors recommend capturing specific benefit metrics to help inform the business and operational case for this technology. This research effort helps to further refine future WiSC research activities and serves as a first step towards understanding how to best apply this technology to better assist ATC personnel and National Airspace System users.

INTRODUCTION

BACKGROUND.

Wildlife hazards, including bird strikes, have been recognized as a reason for concern to pilots and aviation stakeholders since the earliest days of flying. In recent years, the Federal Aviation Administration (FAA) and industry researchers have noted a significant growth in wildlife strike reports [1]. Figure 1 shows the reported wildlife strikes between 1990 and 2013. The increasing trend in bird strike incidents is particularly alarming considering the losses caused by wildlife strikes. Internationally, bird strikes have resulted in more than 255 fatalities and the destruction of 243 aircraft since 1988 [2 and 3]. In the United States, the economic cost associated with wildlife strikes to civil aviation is estimated to be in excess of $625 million per year [1]. J.R. Allan [4] estimated that bird strikes cost commercial air carriers worldwide more than $1.2 billion annually.

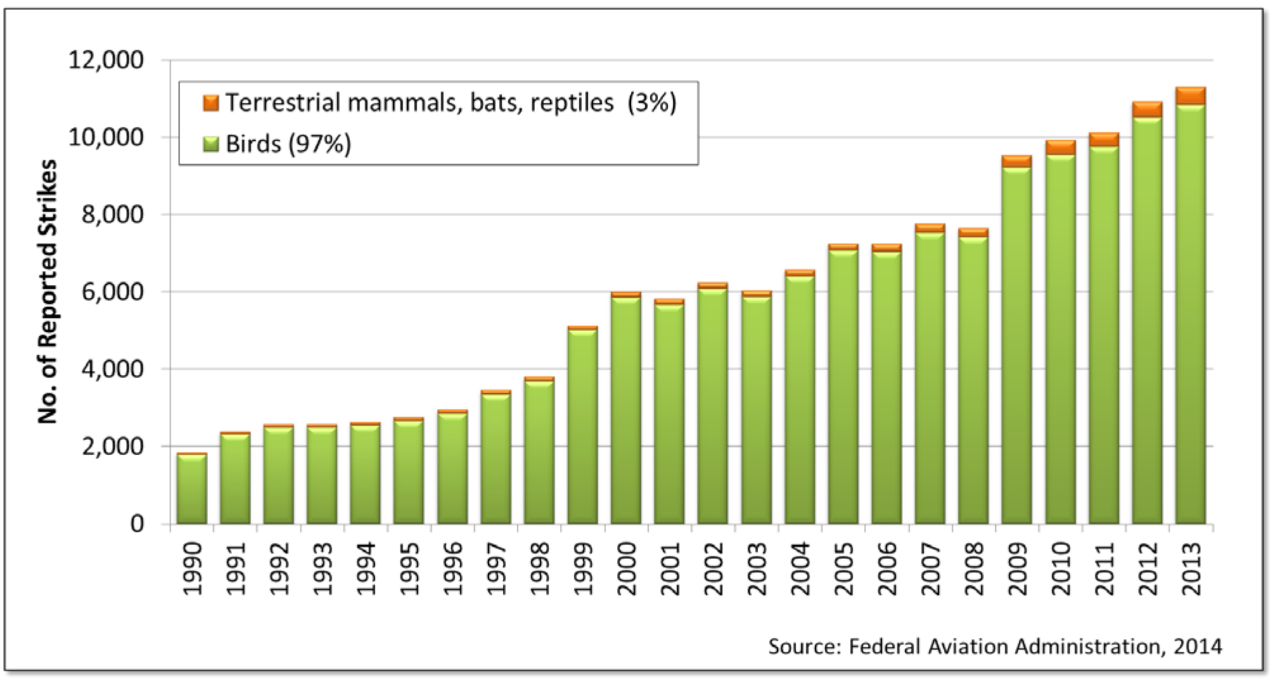
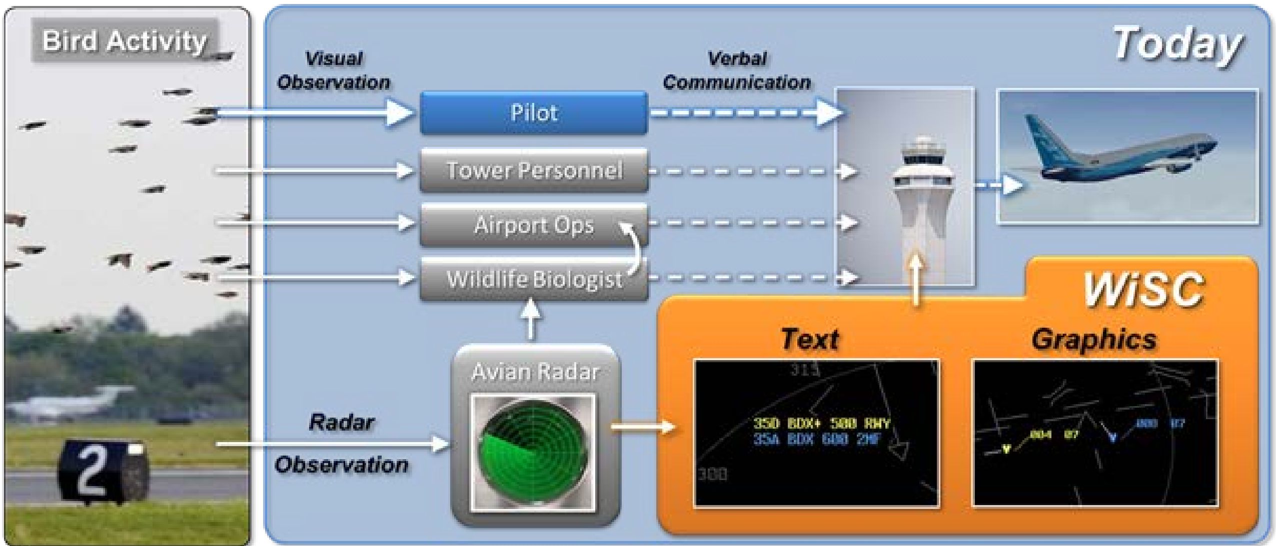


Figure 1. Wildlife Strikes to Civil Aircraft in the United States 1990-2013

The FAA Airport Safety Research and Development Section sponsored the Advanced Concept Development and Validation Branch to develop and mature a concept to provide near real-time bird threat information directly to Air Traffic Control (ATC) personnel in the Airport Traffic Control Tower (ATCT). This concept, termed the Wildlife Surveillance Concept (WiSC), leverages the use of avian radar systems identified in FAA Advisory Circular 150/5220-25, "Airport Avian Radar Systems" [5]. These systems are approved for use by airport operations personnel and wildlife management personnel at civil airports to supplement airport wildlife management efforts to reduce bird threats to aircraft [5 and 6]. Currently, there are avian radar systems deployed at Seattle-Tacoma International Airport (SEA) and Dallas-Fort Worth International Airport (DFW). Figure 2 demonstrates the important differences between current operations and proposed WiSC operations. WiSC processes avian radar data to provide ATCT controllers with a more current and accurate source of information about bird threats.



Current methods used to detect and disseminate bird threat information (blue background) and proposed WiSC methods (orange background) are presented. WiSC provides radar derived, near real-time bird threat information directly to the Air Traffic Control Tower.

Figure 2. Bird Threat Information Flow: Current Operations and WiSC Operations

PURPOSE.

The WiSC Human-in-the-Loop (HITL) Laboratory Demonstration is part of a larger effort to reduce damaging bird strikes at civil airports nationwide by introducing enhanced bird threat information to the ATC environment. The WiSC HITL Laboratory Demonstration's specific purpose was to evaluate alternative methods for presenting supplemental bird threat information to Certified Professional Controllers (CPCs) in the ATCT environment.

METHOD

PARTICIPANTS.

Six CPCs from civilian ATCT facilities served as voluntary participants in the simulation study. Participants were recruited from facilities with the most significant bird strike problems as identified by the FAA National Wildlife Strike Database [2]. All participants were nonsupervisory controllers who were qualified at their facility and held a current medical certificate*. The research team excluded controllers from Philadelphia International Airport (PHL) ATCT in the recruitment process because they would have experience with the airspace and procedures used in the simulation.

*One participant was not a current CPC at an ATCT. Data from this participant was not considered in the analyses contained in this report.

The study required a total of 2 weeks to complete. A new group of three controllers traveled to the FAA William J. Hughes Technical Center Research Development Human Factors Laboratory (RDHFL) each week to participate in the study. All participants worked independent traffic scenarios in an ATCT simulator, as detailed in the study procedure herein. Participants were briefed on their roles, responsibilities, and rights in the simulation and signed an Informed Consent Statement prior to the start of the experiment.

PARTICIPANT BACKGROUND. Participants in the simulation study were from four different ATCT facilities: Denver (DEN), Salt Lake City (SLC), Memphis (MEM), and Orlando (MCO). Participants indicated additional previous experience with five other operational facilities and also reported working a variety of different shifts throughout their careers. All participants reported ATC currency and that they had controlled traffic within the last month. Table 1 provides a summary of the participants' responses to the Background Information Questionnaire.

Table 1. Background Information Questionnaire Responses

Questionnaire Item	Mean (Years)	*SD* (Years)
How long have you been an Air Traffic Controller?	16.3	10.3
How long have you actively controlled traffic in the tower cab environment?	11.7	10.5
How long have you actively controlled traffic in the terminal radar environment?	8.7	12.6

RESEARCH PERSONNEL.

ADVANCED CONCEPT DEVELOPMENT AND VALIDATION BRANCH PERSONNEL. A human factors specialist (HFS) served as the principal investigator and conducted the simulation. The HFS briefed participants, collected data, and led group discussions with controllers. The HFS supervised the operation of the simulation equipment and coordinated the work of the research personnel. An engineering research psychologist chaired independent research discussions to provide organizational, programmatic, and conceptual information regarding WiSC to participants and engaged in group discussion activities with participants. A program analyst assisted with running simulation activities and coordinating participant schedules.

THE ATC SUBJECT MATTER EXPERT PERSONNEL. Two ATC subject matter experts (SMEs) served as part of the research team during the study. The ATC SMEs were retired Philadelphia ATCT supervisors with research and simulation experience. The ATC SMEs were responsible for training participants (airspace and procedures) and for providing participant performance ratings after each traffic scenario. The ATC SMEs also helped in the development of the simulation scenarios, procedures, and materials.

THE RDHFL LABORATORY PERSONNEL. Hardware and software engineers, a computer scientist, and various other laboratory personnel prepared the simulator and ensured that the equipment operated properly.

Three simulation pilots participated in the study. The simulation pilots operated pilot workstations to maneuver the simulation aircraft based upon controller instructions while communicating with controllers using standard ATC phraseology.

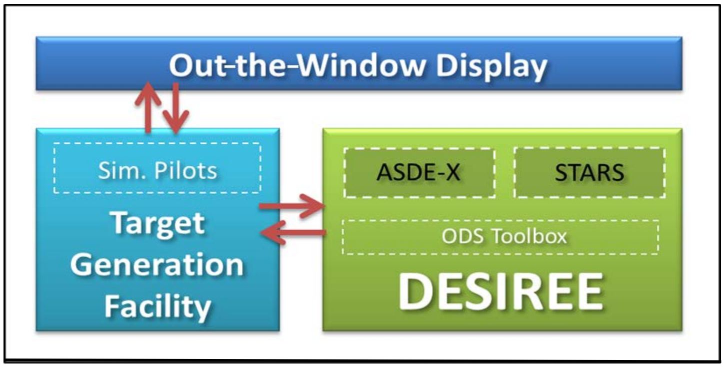
SIMULATION ENVIRONMENT.

TOWER SIMULATOR. The study was conducted in the FAA RDHFL tower simulator located at the William J. Hughes Technical Center. The RDHFL is a state-of-the-art facility with experiment rooms, ATC workstations, and human performance measurement equipment to support aviation human factors research. The simulation environment consisted of the Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) ATC simulator, and the Target Generation Facility (TGF). These two systems work together to provide a realistic ATC out-the-window (OTW) view of the airport surface and its traffic.

SOFTWARE. The tower emulation environment was driven by two specialized ATC simulation software products developed and maintained by the FAA. These two systems, DESIREE and TGF, are described below.

The DESIREE. Software engineers at the FAA William J. Hughes Technical Center developed the DESIREE ATC simulation software to support air traffic research and development, as well as test and evaluation activities. DESIREE provides a flexible platform for researchers to modify the displayed information and functionality of controller workstations to evaluate new ATC concepts and procedures. In the present study, DESIREE emulated the Airport Surface Detection Equipment - Model X (ASDE-X) and Standard Terminal Automation Replacement System (STARS) displays. DESIREE also simulated two notional interfaces for presenting bird threat information on the STARS display.

The TGF. The TGF is a dynamic, real-time air traffic simulation capability designed to generate realistic aircraft targets for HITL simulations. The TGF models aircraft performance characteristics and maneuvers aircraft based upon scripted flight plan data and simulation pilot commands. Commands are issued into TGF through multiple simulation pilot workstations operated by trained simulation pilot personnel. Figure 3 shows a graphical representation of the ATCT simulator environment.



ODS = Operational Display System

Figure 3. Tower Simulator Environment

HARDWARE. The tower simulator consisted of an OTW display, controller workstation, communications system, workload assessment keypad (WAK), audio-visual recording equipment, and simulation pilot workstations (see figure 4). The components are described below.

Figure 4. Tower Simulator Hardware

The OTW Display. Eleven 73-inch, high-definition televisions provided a 270-degree OTW view of the simulated PHL environment.

Controller Workstation. The ATCT simulation platform consisted of one controller-adjustable workstation. DESIREE was configured to emulate the STARS tower display workstation. This workstation consisted of high-resolution displays for the emulated STARS and ASDE-X systems, keyboard, and a trackball. The keyboard and trackball, as well as a controller headset, are shown beneath the STARS display in figure 5. In addition, a WAK was located on the simulation workstation to capture controller workload ratings during the simulation.

Figure 5. Emulated Controller Workstation

Communications System. Controllers used the RDHFL communications system that emulates the Voice Switching and Control System's user interface currently used in the field. The communications system consists of a push-to-talk (PTT) capability with individual relay switchboxes, headsets with microphones, and PTT handsets or foot pedals. The communications system records the time, position, and switch status for every PTT transmission during a simulation.

The WAK. Controllers used the RDHFL WAK device to provide workload ratings using the Air Traffic Workload Input Technique (ATWIT). ATWIT is an unobtrusive and reliable technique used for collecting controller workload ratings as they work traffic in a simulation [7 and 8]. The WAK consists of a touch panel display with ten buttons labeled from 1 to 10. The WAK is connected to a computer that controls the device and records workload ratings. The system is programmable, allowing researchers to select the timing parameters for the study. The system prompts controllers for workload ratings at a selected time interval by emitting a tone and illuminating the keypad buttons. Controllers provided their workload ratings by pressing one of the ten buttons, where 1 indicates very low workload and 10 indicates very high workload. If controllers did not respond before the timeout period, the system recorded a code indicating there was no response. Five minutes was selected as the rating time interval and 10 seconds as the timeout period for this simulation study.

Audio-Visual Recording System. An RDHFL audio-video recording system was used to record controller voice communications and actions during the simulation. Two overhead video cameras were used to record the controller interacting with the simulation. The audio-video recording served as a record of the simulation and was available for post-hoc analysis purposes.

Simulation Pilot Workstations. Three simulation pilot workstations were linked together in a network with the controller workstation. Each simulation pilot workstation consisted of a computer monitor, keyboard, and mouse. A section of the computer monitor depicted a situation display of the airspace and aircraft in the simulation similar to the controller display. The remaining display area contained a list of aircraft assigned to the simulation pilot, flight information, and a user interface to enter flight plan changes into the system. Each simulation pilot was responsible for several aircraft during the simulation. The simulation pilots used the RDHFL communications system to talk to controllers.

AIRSPACE AND TRAFFIC SCENARIOS. PHL ATCT and its surrounding airspace was selected for this simulation study. PHL is currently ranked sixth in the nation in terms of bird strike prevalence. In addition, the research team ATC SMEs had significant familiarity with PHL air traffic operations and procedures.

Simplified versions of both east and west PHL traffic flow configurations were used for the simulation. The research team worked closely with PHL ATC SMEs to simplify associated ATC procedures and traffic flows for several experimental purposes. For example, simplified procedures allowed participants to quickly learn the airspace while minimizing training time needed. Simplified ATC operations also allowed the research team to run a single-person (combined-local) position with automated ground traffic. Finally, simplified ATC operations allowed participants to focus adequate attention to the new bird threat information interfaces that were being evaluated in this simulation study.

The research team restricted the participants' ability to change the display range settings on the STARS display. The display range was set to 12 miles in each simulation run to control unwanted display confounds (e.g., target overlap and dynamic avian radar tag resizing).

BIRD EVENTS. The research team developed an east flow and a west flow bird scenario to inject into the ATCT simulator. Each bird scenario consisted of six independent bird events to represent a wide range of bird threat situations. The research team defined a start and end point, heading (as a series of spatial and temporal coordinates), speed, and altitude for each unique bird event. In addition, characteristics such as species (turkey vultures, small flock, etc.) and bird behavior (circling, east-to-west direction of flight, etc.) were assigned to each bird event. This provided simulation pilots information that supported their communications with participant controllers. The number, total duration, and complexity of bird events were similar across all conditions. Figure 6 shows a spatial representation of the scripted bird events. Appendix A presents a more detailed description of bird events, including start time, end time, speed, and threat duration.

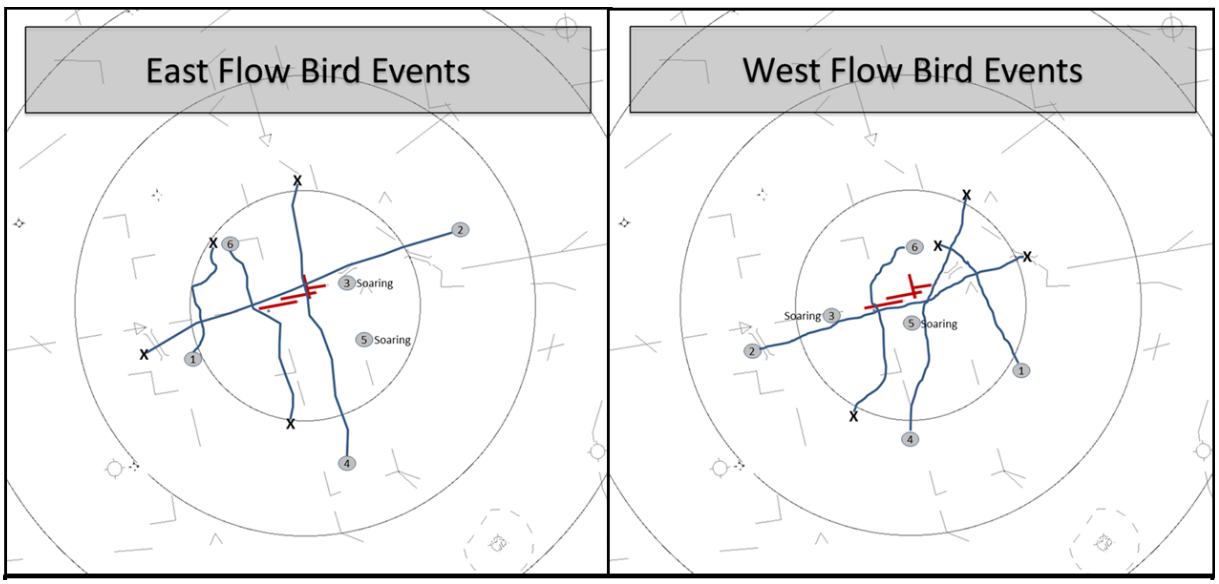


Figure 6. Simulated Bird Events

MATERIALS.

INFORMED CONSENT STATEMENT. Each participant read and signed the Informed Consent Statement before beginning the experiment. The Informed Consent Statement described the purpose of the study, the rights and responsibilities of the participants, and ensured the anonymity of the participants' responses during the simulation (see appendix B).

BACKGROUND INFORMATION QUESTIONNAIRE. Each participant completed the Background Information Questionnaire before beginning the experiment. This questionnaire collected general descriptive information about the participants, including the level and type of ATC experience (see appendix C).

PRE-SIMULATION OPINION QUESTIONNAIRE. The participants completed the Pre-Simulation Opinion Questionnaire prior to starting the simulation. This questionnaire was designed to elicit their opinions on the nature of bird threats in the ATC environment today, their experience dealing with bird threats, and their opinions on potential mitigation methods (see appendix D).

POST SCENARIO QUESTIONNAIRE. The participants completed the Post Scenario Questionnaire (PSQ) after each test scenario. The purpose of this questionnaire was to collect data regarding the controller's experience in the traffic scenario just completed. The PSQ included ratings and open-ended questions about the participant's perception of their performance, workload, and situational awareness. Participants also provided ratings regarding the method of receiving bird threat information just presented. Participants were able to comment about anything they experienced during the scenario that they considered relevant to the study (see appendix E).

THE WISC INTERFACE EVALUATION QUESTIONNAIRE. The participants completed the WiSC Interface Evaluation Questionnaire on the final day of the simulation. This questionnaire was designed to elicit important information regarding participant preference for bird threat information displayed in the simulation study (see appendix F).

EXIT QUESTIONNAIRE. The participants completed the Exit Questionnaire after performing all traffic scenarios. The purpose of this questionnaire was to collect data regarding the participant's experience throughout the entire experiment. The participants provided ratings about the realism of the simulation, including the airspace, traffic scenarios, and ATC equipment. Participants also provided ratings that compared the experimental conditions tested in the simulation. The Exit Questionnaire included both rating style and open-ended style questions. Participants were able to comment about anything they experienced during the entire experiment that they considered relevant to the study (see appendix G).

OBSERVER RATING FORM. After each test scenario, ATC SMEs used the Observer Rating Form (ORF) to provide performance ratings for each participant. The ORF was developed by researchers and SMEs in the RDHFL to evaluate new ATC concepts and procedures by observing controller performance in HITL simulations [9 and 10]. The ORF consisted of several rating scales designed to assess different aspects of ATC performance, such as resolving aircraft conflicts, sequencing aircraft, prioritizing tasks, communicating effectively, and maintaining situation awareness. Portions of the ORF were modified to better suit the purpose of the research. For example, categories relevant to bird advisory communication were added, as well as a category for rating effective usage of prototyped bird threat interfaces (see appendix H).

EXPERIMENTAL DESIGN.

This simulation was a single-factor, within-subjects design. The independent variable in this simulation study was the method used to present bird threat information to the participant. Each participant was exposed to four conditions: a baseline condition and three levels of the independent variable (bird threat presentation method). The baseline condition simulated current-day ATCT operations (i.e., pilot reports of bird activity). Presentation of the independent variable was counterbalanced to control for order effects (i.e., learning). Please see the PROCEDURE section for more details on the experimental presentation order.

EXPERIMENTAL CONDITIONS. The experiment consisted of four alternative methods for presenting bird threat information to tower controllers: baseline, WiSC target, WiSC text, and WiSC supervisor (see figure 7). The baseline condition relied on pilot reports, as is done in the National Airspace System (NAS) today. The three remaining WiSC conditions represented different ways in which avian radar data might be processed and provided to a controller. During the WiSC target and WiSC text conditions, the information was provided directly to the controller via the STARS primary tower radar display. In the supervisor condition, the supervisor was responsible for providing controllers with hand-written textual information identifying the bird threat location.

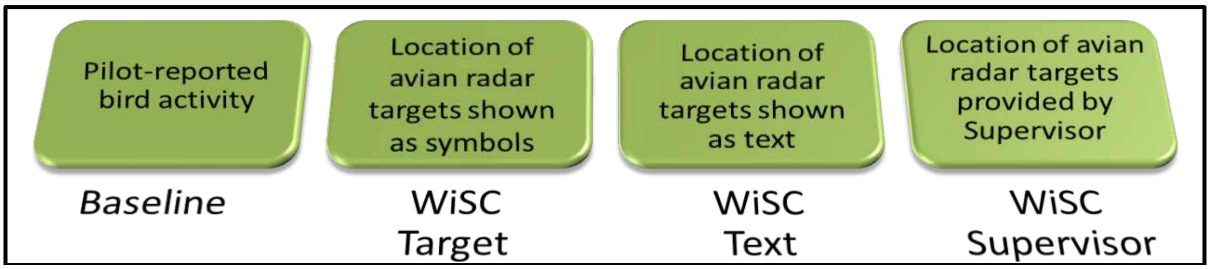


Figure 7. Experimental Conditions

In all WiSC conditions, WiSC information was only presented when birds where expected to be a factor with aircraft (departure/arrival path proximity, corresponding altitude, etc.) and was removed as soon as the birds were no longer a factor. This relieved participants from the mandatory 15-minute reporting requirement currently in place [11]. In addition, the participants were not required to confirm the radar-provided bird information through verbal communication with pilots. Participants were instructed to issue bird advisories to individually affected aircraft as necessary and to avoid "blanket broadcasts" of bird threat information.

Baseline Condition. The baseline condition contained pilot reports (PIREPS) of bird activity much like those made in current operations. Simulation pilots followed timed scripts and delivered aircraft-specific location information on identified bird threats. In this baseline condition, the controllers were instructed to use the same techniques and procedures for handling this information that they would use in the field. For example, according to FAA Order JO 7110.65W, "Air Traffic Control" [11], controllers must report any bird threat information for a period of 15 minutes or until they can confirm that the birds are no longer a threat. To do this, controllers will continue to query subsequent aircraft (landings and departures) about previously reported bird threats.

The WiSC Target Condition. The WiSC target condition provided controllers with precise and current bird threat information in the form of a target displayed on the STARS primary tower radar display. The WiSC target consisted of a position symbol, direction of flight indicator (heading), and altitude and speed information. The WiSC target information was updated simultaneously with STARS display updates. The WiSC target was color coded by threat level. Bird activity meeting the minimum threat threshold level was presented in blue text, while more significant bird activity (e.g., size of birds or flock) was presented in yellow. Figure 8 provides an example of both levels of bird threats used in this experimental condition.

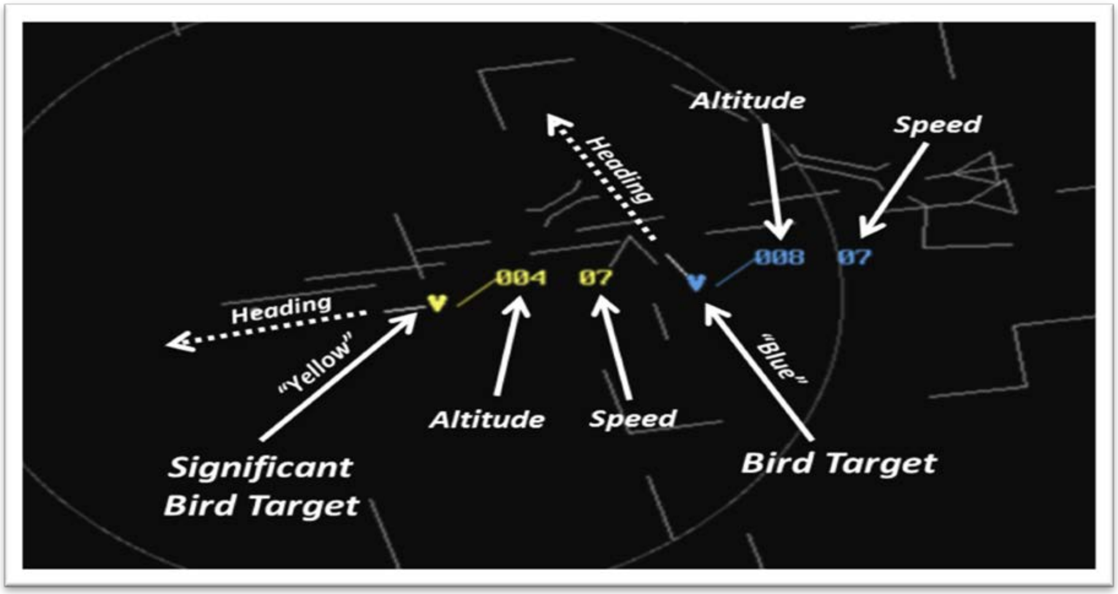


Figure 8. The WiSC Target Interface

The WiSC Text Condition. The WiSC text condition presented bird threat information in textual form in the upper-left corner of the STARS primary tower radar display. The text provided controllers with precise and current bird threat information. Participants were not able to change the WiSC text box position or formatting for purposes of this simulation study.

When a simulated bird threat was identified or updated, an audible "bird call" was activated and a text message appeared. The text message (see figure 9) contained the affected runway, a three-letter identifier indicating the target was a bird (BDX), severity of the threat, altitude of the target, and the target's relative location (given in miles from the airport). The threat location was provided as a general area (e.g., 2-mile final) rather than a precise point as was the case in the WiSC target condition. The threat severity was redundantly coded by color and symbol. Bird activity meeting the minimum threat threshold level was presented in blue text, while more significant bird activity was presented in yellow text with a plus (+) sign next to the bird identifier.

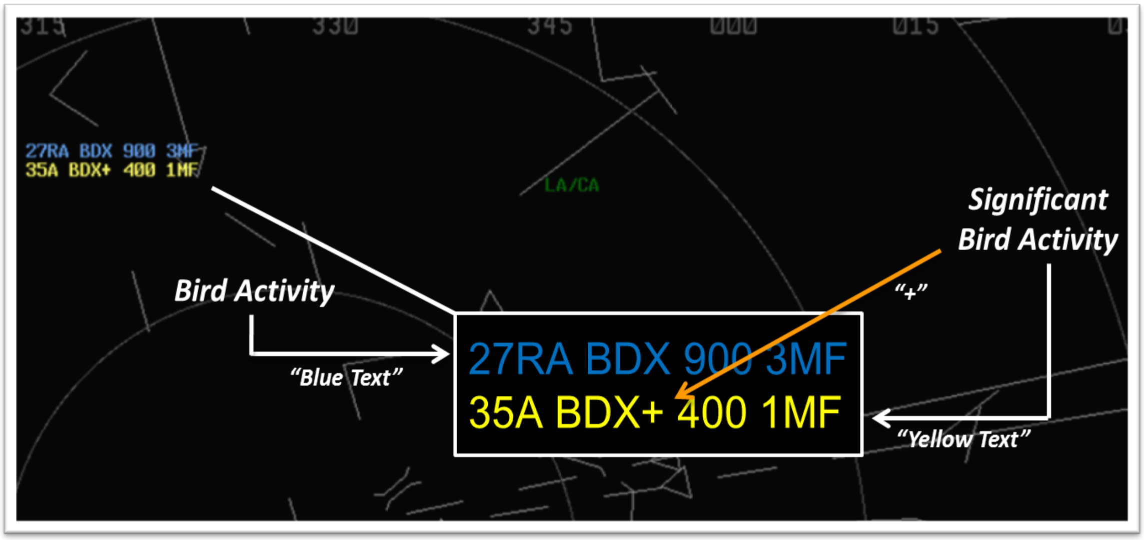


Figure 9. The WiSC Text Interface

The aural alert tone used in this simulation was a Mexican Red Parrot call. The aural alert served to notify participants that new or updated bird threat information was available and persisted for approximately 2 seconds. The aural alert also permitted controllers to continue working on higher-priority or visually demanding tasks until they were able to view the bird threat text information. In addition to the aural alert, any new textual information flashed on the display for 10 seconds to differentiate it from other previously available bird threat information.

The WiSC Supervisor Condition. During the WiSC supervisor condition, the over-the-shoulder ATC supervisor provided controllers with precise and current bird threat information in the form of hand-written textual information. The type and format of the bird threat information was identical to the WiSC text condition, with a few notable exceptions. First, the information was handwritten on a blank flight strip (see figure 10) as opposed to being presented on the radar display. Next, there was no color coding for threat level (i.e., only the plus (+) symbol was used to differentiate threat level). Finally, the aural tone (bird call) was not used in this condition. Instead, the ATC supervisor waited for an operationally acceptable time and then verbally conveyed the updated information to the participant while handing them the flight strip.

Figure 10. The WiSC Supervisor Bird Threat Information

SIMULATION MEASURES.

Objective Measures. PTT communications represented the primary objective data captured. The simulator captured the time, duration, and source of the communication (controller or simulation pilot) for all conditions. The data were analyzed to compare the frequency, duration, and nature of controller and pilot communications across conditions. In addition, the content of voice communications related to bird threats was analyzed.

Subjective Measures. Subjective data were provided by the participants and ATC SME supervisors. The participants provided questionnaire and workload ratings. ATC SME supervisors provided over-the-shoulder ratings of ATC performance during each condition.

The participants' questionnaires were among the primary sources of data and included PSQs completed at the conclusion of each run, an Interface Evaluation Questionnaire, and an Exit Questionnaire (see appendices F and G respectively). The questionnaires provided insight into multiple dimensions of controller performance and preference (workload, situational awareness, interface preference, information value, etc.).

When prompted by a tone, participants provided instantaneous workload ratings at 5-minute intervals on the WAK device. This data provided an additional assessment of workload based on fluctuations in traffic levels and ATC duties over time instead of the single post-scenario rating captured on the PSQ.

The ATC SME supervisor provided subjective ratings of controller performance for each of the experimental conditions. As former supervisors at an ATCT, they were experienced in observing and evaluating controller performance while training developmental controllers. In addition, much of their experience was from PHL ATCT.

PROCEDURE.

Table 2 shows a simplified version of the daily schedule of activities for the participants in the simulation study. The study consisted of two groups of three controllers. Each group of participants consisted of three controllers who were released from their facility for 1 week to participate in the WiSC HITL Laboratory Demonstration. The first group of controllers traveled to the William J. Hughes Technical Center on Monday and traveled back home that Friday. This procedure was then repeated with a new group of controllers in the second week of the study.

Table 2. Daily Schedule of Activities

Tuesday		Wednesday		Thursday	
8:20-8:30	Introductions	8:20-9:00	Experimental Run 2	8:20-9:00	Experimental Run 9
8:30-9:00	Concept Briefing	9:00-9:20	Break	9:00-9:20	Break
9:00-10:00	Airspace Briefing	9:20-10:00	Experimental Run 3	9:20-10:00	Experimental Run 10
10:00-10:20	Break	10:00-12:20	Break	10:00-12:20	Break
10:20-11:20	Training Run 1	10:20-11:00	Experimental Run 4	10:20-11:00	Experimental Run 11
10:20-12:20	Lunch	11:00-11:20	Break	11:00-11:20	Break
12:20-1:20	Training Run 2	11:20-12:00	Experimental Run 5	11:20-12:00	Experimental Run 12
1:20-1:40	Break	12:00-1:40	Lunch	12:00-1:20	Lunch
1:40-2:40	Training Run 3	1:40-2:20	Experimental Run 6	1:20-2:00	Exit Forms
2:40-3:00	Break	2:20-2:40	Break	2:00-4:00	Debrief
3:00-3:40	Experimental Run 1	2:40-3:20	Experimental Run 7		
3:40-4:20	Discussion	3:20-3:40	Break		
		3:40-4:20	Experimental Run 8		

On Tuesday, Wednesday, and Thursday, the controllers participated in the experiment. On the first day of the study, the participants were briefed on the concept background, project goals, and airspace procedures used in the simulation study. The participants also completed the Informed Consent Statement and the Background Information Questionnaire prior to starting the simulation study.

Participants performed three 1-hour joint training runs, on the first day of the simulation study. During these training runs, participants took turns controlling the traffic for 20 minutes each while an ATC SME responded to questions and provided feedback on ATC performance. Participants remained "plugged in" to the controller-pilot voice communication system at all times during the training runs whether they were actively controlling traffic or observing.

Participants began experimental runs at the end of day one. Each experimental run was 40 minutes long, and only one participant ran the simulator during each session. Each experimental run was followed by a PSQ designed to assess the experimental run just completed. Each participant completed four experimental runs, representing a total of 12 data collection sessions each week and a grand total of 24 runs in the entire study. Table 3 provides the counterbalanced presentation order for experimental runs during the 2-week WiSC simulation study.

Table 3. Experimental Presentation Order

Participant	Experimental Presentation Order			
1	Baseline	WiSC Target	WiSC Supervisor	WiSC Text
2	WiSC Target	WiSC Text	Baseline	WiSC Supervisor
3*	WiSC Text	WiSC Supervisor	WiSC Target	Baseline
4	WiSC Supervisor	Baseline	WiSC Text	WiSC Target
5	Baseline	WiSC Target	WiSC Supervisor	WiSC Text
6	WiSC Target	WiSC Text	Baseline	WiSC Supervisor

*Participant 3's data was excluded from analyses.

Because data collection sessions could only be performed by one participant at a time, additional research activities were developed to engage participants between simulation runs. These sessions provided the opportunity to capture other valuable data to support further development of the concept. These activities included an in-depth concept briefing, a briefing on bird-related news coverage, and two separate Concept of Operations sessions led by The MITRE Corporation. The sessions provided operational feedback on the current state of bird information handling in the ATC environment and helped identify opportunities to improve bird threat information handling in the future. For more detailed information on the individual schedule for these sessions by participant see appendix I.

On the afternoon of the final day, the controllers completed an Interface Evaluation Questionnaire and an Exit Questionnaire. Following this, a formal debrief session was held to discuss participant insights regarding the value of and utility of WiSC information, interface options, implementation strategy, and other key areas of interest.

RESULTS AND DISCUSSION

The research team collected a variety of objective and subjective measures in this simulation study. All of the analyses focused on the bird threat experimental condition (baseline, WiSC target, WiSC text, and WiSC supervisor). The research team provided qualitative summary data throughout and, where possible, used inferential statistics to compare conditions. All inferential statistical analyses were performed using the Friedman Analysis of Variance (ANOVA) by ranks (nonparametric equivalent of a repeated measure ANOVA) using a decision criteria of $\alpha \leq 0.05$ (marginal effects $\alpha \leq 0.10$ are also reported). Significant effects were followed by performing pairwise comparisons using the Wilcoxon signed-ranks test (nonparametric equivalent to a *t*-test) to determine which conditions were significantly different. The research team controlled for Type I errors across these comparisons at $\alpha = 0.05$ criteria using the Least Significant Difference procedure [12]. Appendix J provides justification for the approach in analyzing this data.

The results of the simulation study are grouped by activity in the following sections. The data and methods of analysis used are described. All graphs present means and standard error bars unless otherwise noted.

QUESTIONNAIRES.

Questionnaire items consisted of open-ended, forced choice, and rating scale questions. A variety of different anchors were used for the rating scale questions. As a rule, low-rating values were associated with low/less/disagree, whereas high-rating values were associated with high/more/agree. Figure 11 shows examples of rating scale anchors used in the questionnaires. All questionnaires can be found in the appendices.

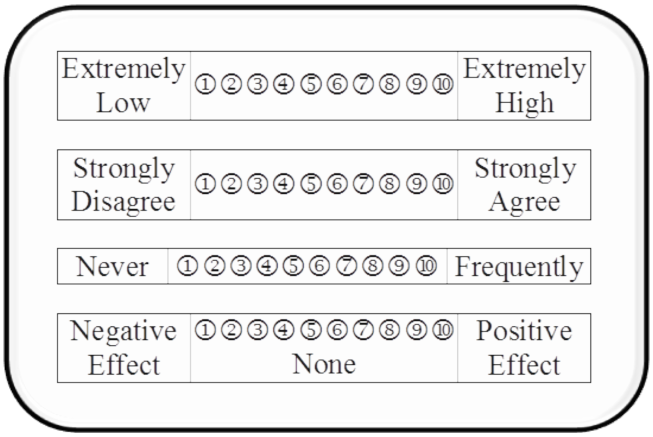


Figure 11. Ten-Point Rating Scale Anchors Used in Questionnaires

PRE-SIMULATION OPINION QUESTIONNAIRE. The Pre-Simulation Opinion Questionnaire was designed to gauge participant's thoughts on several topics related to bird threats at their current facility prior to participating in the simulation study. Participants indicated that they were relatively unaware of avian radar research (*M* = 2.8, *SD* = 2.2) currently being conducted. Participants agreed that birds play a significant role in their daily activities at their facility (*M* = 8.80, *SD* = 1.09), and that those bird hazards contribute significantly to their workload (*M* = 7.2, *SD* = 1.92). Participants estimated that birds impacted their facility an average of 7.4 times a day (*SD* = 6.94) on a typical day and 30.25 (*SD* = 30.82) during peak times.

Participants reported experiencing a full range of operational complications due to bird strikes. These complications included pilot requests to delay departure, precautionary landings, emergency landings, and aborted landings. One participant reported that they often manage aircraft that experience significant bird strike damage, and that bird strike events require them to complete a significant amount of additional paperwork.

Participants suggested that issuing bird advisories becomes repetitious and that the quality of the bird threat information quickly deteriorates over time. Despite the fact that position and altitude information is quickly degraded, controllers are still obligated to pass along the information for 15 minutes or until they determine the threat is no longer a factor. Position and altitude information that is outdated is not useful to controllers.

Bird threat information also becomes less valuable to pilots as the time since the last report increases. Two participants commented that the Air Traffic Information Service (ATIS) runs a generic bird activity message 24 hours a day and, therefore, is of limited value. This generic message typically includes very little information and instead advises there is “bird activity in the vicinity of the airport.” This ATIS broadcast information is typically too generic to be useful to pilots as it does not reference the time of day, location, or altitude of the threat.

POST SCENARIO QUESTIONNAIRES. The following sections present the PSQ results in terms of general and WiSC-specific items. General items asked participants to draw comparisons across all conditions, whereas WiSC-specific items restricted comparisons to WiSC conditions only.

All Conditions.

Simulation Realism Ratings. Participants were asked to rate the ATC realism and simulation pilot realism after each completed scenario. Participants rated ATC realism and simulation pilot realism high in all scenarios. The analysis of differences across conditions was nonsignificant, χ^2 (3, N = 5) = 2.64, p = .19 for ATC realism and χ^2 (3, N = 5) = 2.27, p = .51 for simulation pilot realism. The mean and standard deviation for simulation realism are plotted in figure 12.

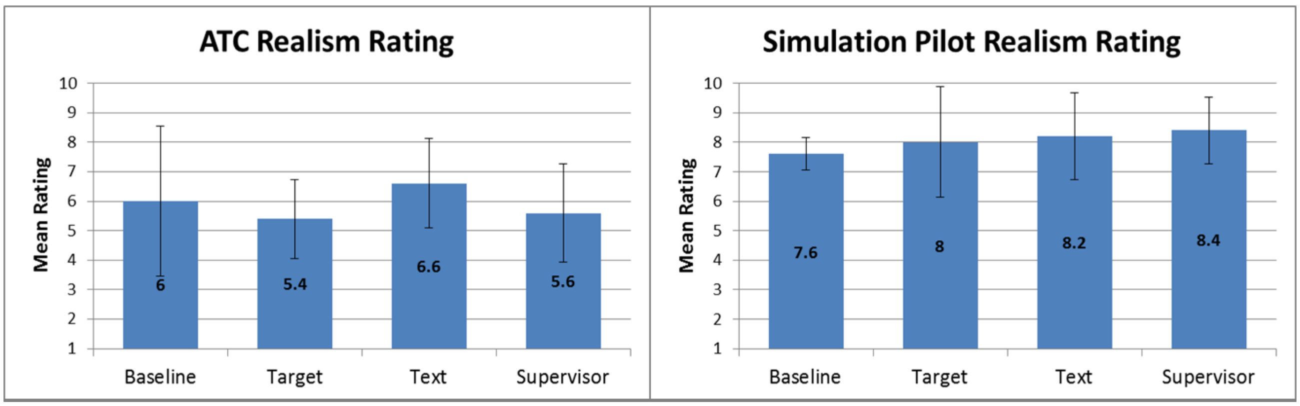


Figure 12. Simulation Realism Ratings

These analyses suggest that the realism of the simulation was acceptable. It was concluded that the laboratory setup, traffic scenarios, and experimental manipulations were realistic and consistent throughout the simulation across all conditions.

The PSQ Scenario Overall Workload Rating. The research team considered the potential of increased controller workload to be one of the most important challenges in presenting more current and precise bird threat information to ATC users. PSQ workload ratings were one of several methods the research team used to quantify the impact of supplemental bird threat information (WiSC) on controller workload. The results of the PSQ workload analysis were nonsignificant, χ^2 (3, N = 5) = 0.717, p = .87, indicating that the research team could not detect a statistical difference in self-reported subjective PSQ workload ratings across conditions. Figure 13 shows the mean and standard deviation for PSQ workload ratings.

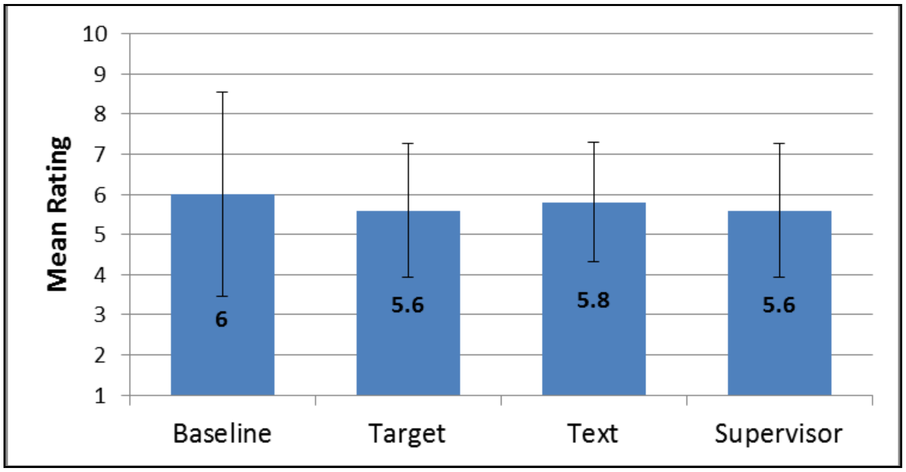


Figure 13. Post Scenario Workload Rating

As stated above, the examination of potential workload differences across conditions is a key consideration in this simulation study. The analysis shows that the implementation of supplemental bird threat information (WiSC) did not result in a statistically significant difference in controller post scenario workload ratings.

Contribution of Birds to Workload Rating. The participants were asked to rate the contribution of birds to their overall workload after completing each scenario run. There was a statistically significant effect of condition on the contribution of birds to workload rating, χ^2 (3, N = 5) = 9.51, p = .023, indicating a difference in participant ratings across conditions. Follow-up pairwise comparisons showed significant differences between the baseline condition and the WiSC target condition (z = 2.6, p = .039) and the baseline and WiSC text condition (z = 2.03, p = .042). Marginal differences were found between the baseline condition and the WiSC supervisor condition (z = 1.76, p = .078) and between the WiSC target and WiSC text condition (z = 1.85, p = .062). All other comparisons were nonsignificant. Figure 14 shows the mean and standard deviation for each condition.

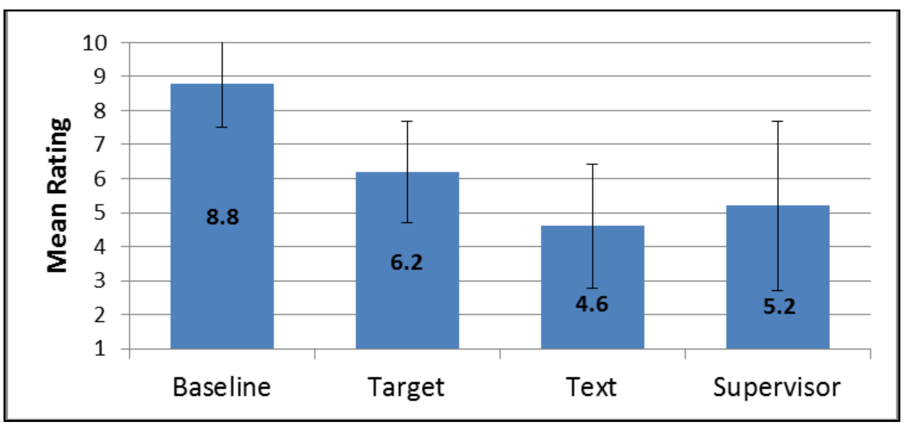


Figure 14. Contribution of Birds to Workload Rating

Workload can be viewed as an accumulation across multiple sources, particularly in complex domains like ATC. Therefore, it is possible for workload to be rated similarly across two scenarios but vary on individual contributors to overall workload. In this case, the data indicates that birds were viewed as a bigger contribution to overall workload ratings in the baseline condition compared to the WiSC conditions. In addition, the WiSC target condition was rated marginally higher in workload rating than the WiSC text condition but not significantly higher than the WiSC supervisor condition.

Impact of Birds on ATC Situational Awareness Rating. The participants were asked to rate the impact of birds on ATC situational awareness after completing each scenario run. There was a statistically significant effect of condition, χ^2 (3, N = 5) = 7.95, p = .047, indicating differences in participant ratings between conditions. Follow-up pairwise comparisons showed significant differences between the baseline condition and the WiSC target condition (z = 2.07, p = .038), and the baseline condition and WiSC text condition (z = 2.02, p = .043). All other comparisons were nonsignificant. Figure 15 shows the mean and standard deviation of each condition.

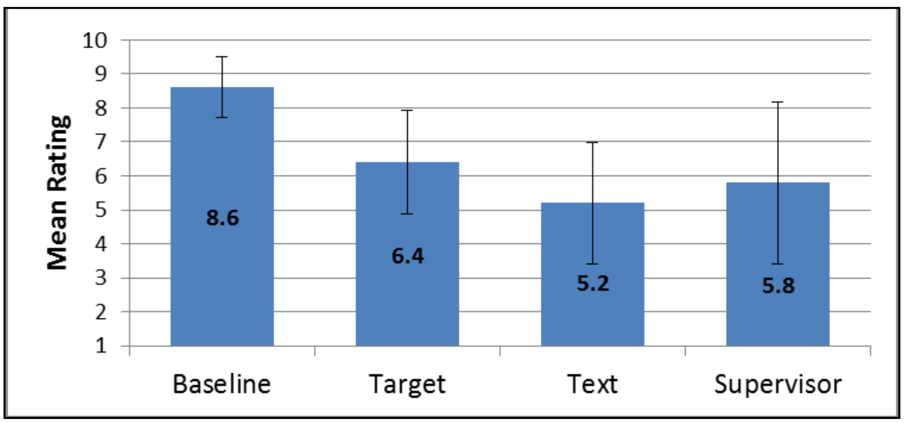


Figure 15. Impact of Birds on ATC Situational Awareness Rating

By definition, bird threat information is advisory in nature, both in the field today and as implemented in this simulation study. Controllers manage this, and other safety information, while performing their primary ATC duties. Therefore, the research team would have expected that ATC situational awareness should not be affected by bird threats. However, the data show that birds impacted ATC situational awareness in the baseline condition significantly more than in the WiSC target and WiSC text conditions. It is unclear if these findings are a product of the simulation environment (e.g., avian radar research project) or a product of typical ATC operational behaviors (e.g., attempting to provide the best services to NAS users).

Rating of Time Spent Looking at Radar. After each experimental run, participants rated the time that they spent looking at the radar display compared to a typical day at their facility. There was a marginal difference, χ^2 (3, N = 5) = 6.75, p = .08, in the rating of time spent looking at the radar between conditions. Figure 16 shows the mean and standard deviation across conditions.

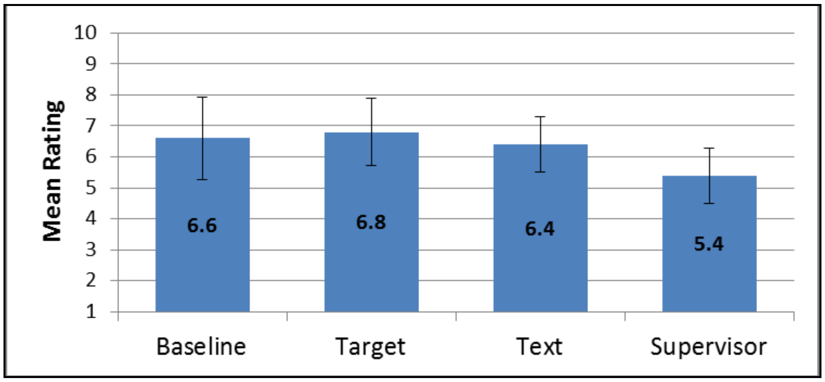


Figure 16. Rating of Time Spent Looking at Radar

Time spent looking at the radar was an important consideration to measure because putting additional information on the radar display could theoretically lead to an increase in time spent looking at the radar display. This phenomenon, casually referred to as "BRITE eyes" (a reference to Digital Bright Radar Indicator Tower Equipment—a type of tower primary radar display), alludes to the fact that users may pay too much attention to displays at the expense of decreased time looking out the tower cab windows.

If any differences existed in "time spent looking at the radar" between conditions the research team would have expected to find those differences between the baseline condition and WiSC conditions. However, the mean rating for baseline (M = 6.6), WiSC target (M = 6.8), and WiSC text (M = 6.4) are nearly identical. Therefore, the research team concluded that the marginal differences found between the WiSC supervisor and WiSC target conditions were most likely attributed to chance or other experimental artifacts.

Perceived Number of Bird Events. The participants were asked to rate the total number of bird events that they perceived in the scenario compared to the number of bird events experienced at their facility during typical times. The research team compared the responses across conditions. There were marginal differences between the perceived number of bird events by condition, χ^2 (3, N = 5) = 7.63, p =.053. Figure 17 shows the mean and standard deviation across conditions on perceived number of bird events.

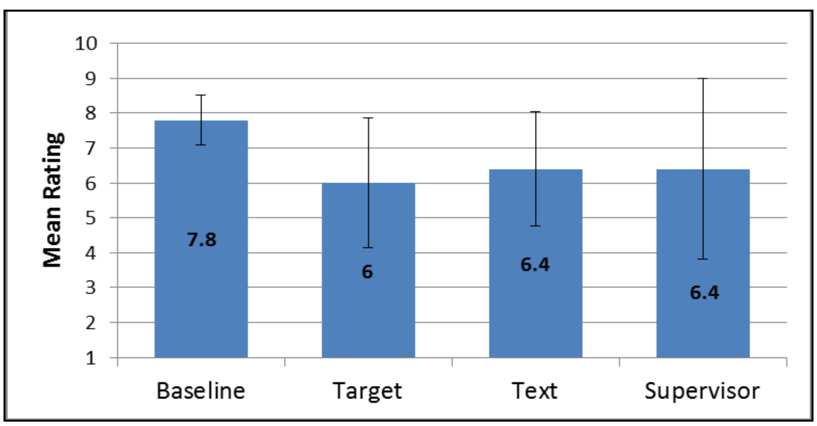


Figure 17. Perceived Number of Bird Events

There was substantial variability in the ratings given in WiSC conditions, and particularly in the WiSC supervisor condition. Although only marginally significant differences were found, the data suggest that participants perceived more bird events in the baseline condition compared to the WiSC conditions. This is important to note because the actual number of bird events were constant throughout all simulation runs. It was theorized that this increased number of perceived bird events is likely due to the more intensive nature of dealing with multiple PIREPS and the cognitive effort that is associated with keeping verbally reported spatial information current for 15 minutes.

The WiSC-Only Conditions.

Value of WiSC Information. The participants were asked to rate the value of WiSC information after completing each scenario run. There were significant differences in the responses to this question across conditions, χ^2 (2, N = 5) = 8.58, p = .014. Follow-up pairwise comparisons showed significant differences between the WiSC target and WiSC supervisor conditions (z = 2.03, p = .042). Marginal differences were also found between the WiSC target and the WiSC text conditions (z = 1.63, p = .100) and between the WiSC text and WiSC supervisor conditions (z = 1.85, p = .063). Figure 18 shows the mean and standard deviation across conditions.

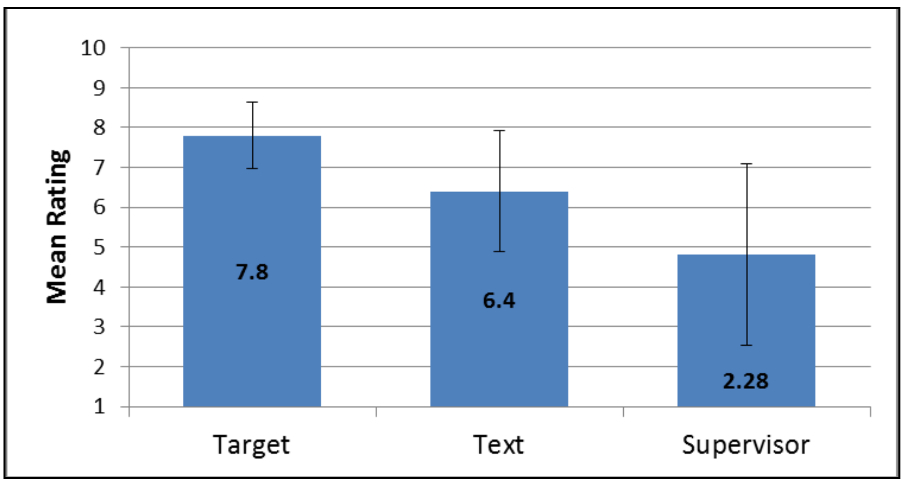


Figure 18. Value of WiSC Information

The findings emphasized the nature of information contained in each condition. The WiSC target condition provided the most precise position information for bird threats and thus was rated more highly in terms of information value than the supervisor condition and marginally higher than the WiSC text condition. Surprisingly, the value of the supervisor-provided information tended to be rated lower than that provided in the WiSC text condition, even though the actual message content was identical. This suggests there were additional factors contributing to the perceived value of the information. Subsequent exit interviews indicated that one reason for this may be that participants recognized that supervisors have competing responsibilities that may limit or interfere with their ability to pass along the WiSC information.

Usefulness of WiSC Information Presentation. The participants were asked to rate the usefulness of the WiSC information presentation after completing each scenario run. The analysis of the differences between conditions was statistically significant for this question, χ^2 (2, N = 5) = 7.00, p = .003. Follow-up pairwise comparisons showed significant differences between the WiSC text and WiSC supervisor conditions (z = 2.03, p = .042) and marginal differences between the WiSC target and WiSC supervisor conditions (z = 1.84, p = .066). The research team was not able to detect a statistically significant difference between the WiSC target and WiSC text conditions. Figure 19 shows the mean and standard deviation across conditions.

Participants rated the WiSC target condition as the most useful presentation method, followed by the WiSC text and WiSC supervisor conditions. This higher rating for the WiSC target condition is most likely attributed to the more precise and current bird threat information provided in that condition. The substantial variability in responses (particularly in the WiSC supervisor condition) made it difficult to find statistically significant differences where they would otherwise exist (e.g., marginal statistical difference between WiSC target and supervisor conditions).

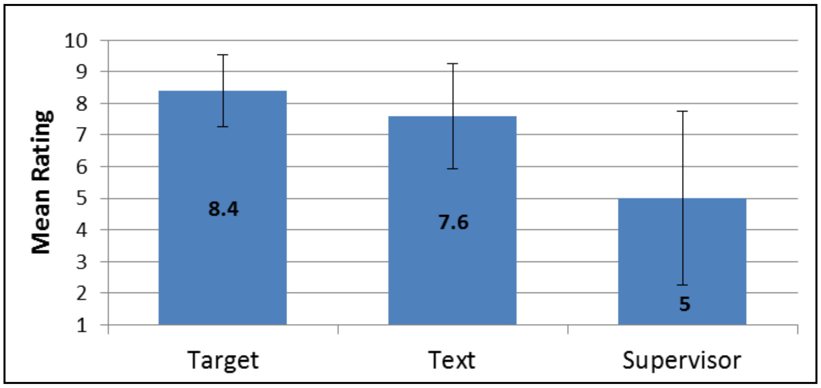


Figure 19. Usefulness of WiSC Information

Ease of Understanding WiSC Information. The participants were asked to rate the ease of understanding the WiSC information presentation method after completing each scenario run. Analysis of the effect of condition on the rating was statistically nonsignificant, χ^2 (2, N = 2) = 0.118, p = .943. Figure 20 shows the mean and standard deviation in each condition.

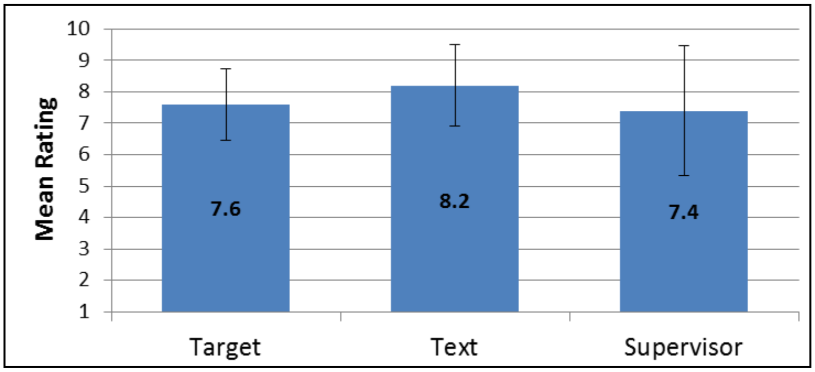


Figure 20. Ease of Understanding WiSC Information

Although the WiSC text condition was rated as slightly easier to understand than the other WiSC conditions, the difference was not statistically significant. In fact, participant ratings indicated that all WiSC presentation methods were easy to understand.

WiSC Information Quality and Completeness. The participants were asked to rate the extent that the WiSC condition provided all of the information required to provide bird advisories to pilots. Participants rated the WiSC target condition as the most complete presentation method, followed by the WiSC text condition and the WiSC supervisor condition. The analysis of the effect of condition on responses was statistically significant, χ^2 (2, N = 5) = 7.00, p = .003. Follow-up pairwise comparisons showed significant differences between the WiSC target and WiSC supervisor conditions (z = 2.03, p = .042). There were marginal differences between the WiSC target and WiSC text conditions (z = 1.89, p = .059) and between the WiSC text and WiSC supervisor conditions (z = 1.84, p = .066). Figure 21 shows the mean and standard deviation across conditions.

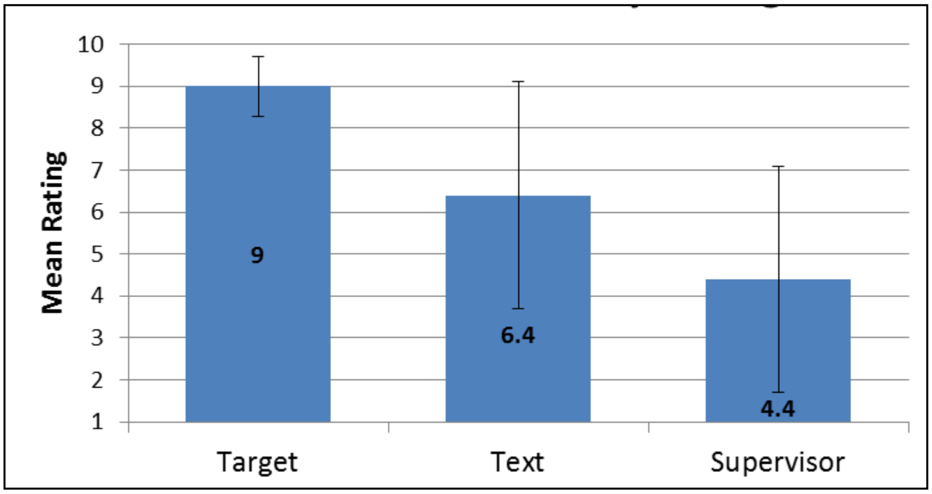


Figure 21. The WiSC Information Quality Rating

Although participants clearly rated the WiSC target condition most highly in terms of information quality, there was substantial variance in responses for the WiSC text and WiSC supervisor conditions. Considering that variance limits the ability to detect statistical differences (particularly in sample sizes as small as this), the research team viewed these results as a convincing argument of differences in information quality between conditions.

Impact of WiSC on Workload. Participants rated the impact of WiSC on their overall workload after completing each scenario run. There were marginal differences in the responses to this question across conditions, χ^2 (2, N = 5) = 5.765, p = .056. Figure 22 shows the mean and standard deviation across conditions.

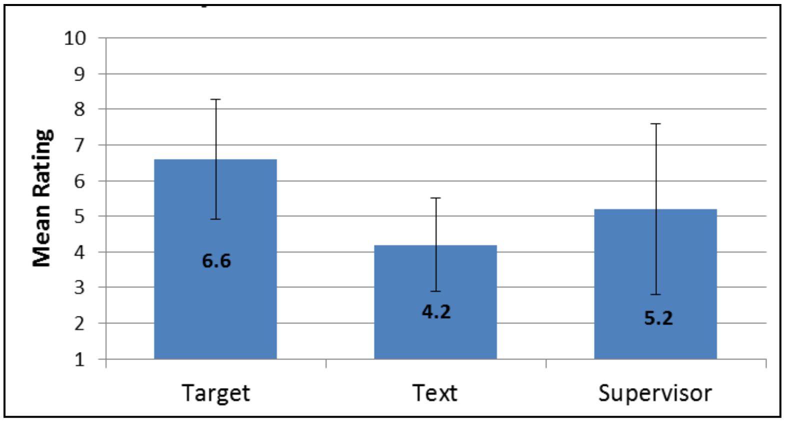


Figure 22. Impact of WiSC on Workload

Although the results were marginal, there was a trend in the data. Participants tended to rate the WiSC target condition as having the highest impact on workload, followed by the WiSC supervisor and the WiSC text conditions. The marginal increase in the WiSC target condition was most likely due to the more detailed and complex nature of information presented compared to the other conditions. For example, one participant reported that they treated the bird threats too much like “traffic” (aircraft targets) in the WiSC target condition. However, it was noted that the impact on workload rating is still considered moderate (i.e., 4-7 on a 10-point scale) in all conditions.

THE WISC INTERFACE EVALUATION QUESTIONNAIRE. The purpose of this questionnaire was to allow participants to give their overall preferences for the method of presenting bird threat information. Participants rated presentation method, display system, and display symbology.

The WiSC Presentation Method.

Interface Preference. Participants rated both the WiSC target and WiSC text option highly favorably. Three of the five participants responded that they preferred the WiSC target presentation while two participants preferred the WiSC text presentation. The most common reason stated for WiSC target preference was that it included the best bird threat information available (precise target position) to provide to NAS users. The primary reason given for preferring the WiSC text interface was that it was extremely easy to use and required very little additional cognitive effort to interpret. No participants showed a preference for the WiSC supervisor presentation.

Four of the five participants responded that they least preferred the WiSC supervisor presentation. Participants reported several issues in the supervisor condition, including the problem of shared responsibility of bird threat information between controllers and supervisors. One participant least preferred the WiSC target interface because they treated the bird information just like traffic and viewed WiSC as potentially increasing workload. This participant later agreed that the option for a controller to select their desired level of information display (target versus. text) would solve this issue. Figure 23 shows the most- and least-preferred WiSC interface.

Figure 23. The WiSC Interface Ratings

Initial Recipient of WiSC Information. The participants were asked who the initial recipient of WiSC information should be. The options for this response were (1) direct to the controller, (2) direct to the supervisor (who would then disseminate information to controllers as needed), or (3) a combined approach where all severe threats were displayed directly to the controller while more mundane information was available to the supervisor for dissemination (if deemed necessary).

Four of the five participants responded that all bird threat information should go directly to the controller. One participant responded that only severe threat information should go directly to the controller, and the supervisor should use discretion to disseminate the less-severe information as needed. However, all participants agreed that significant bird threats need to be displayed directly to the controller.

Participants indicated a strong concern for sharing discretionary responsibility if bird threat information was initially received by the supervisor only. One participant stated "Give it (bird threat information) to me at my position or don't give it to me at all." In addition, participants reported that in many situations it would not be possible for the supervisor at their facility to disseminate bird threat information (e.g., physical ATCT layout, number of control positions, workload, and competing responsibilities).

The WiSC Display System. The participants were asked where the WiSC information should be displayed. Participants responded unanimously that WiSC target information should be located on the primary tower radar display.

Three of the five participants indicated that WiSC text information should also be located on the primary radar display. The other two participants had different responses. One chose the Information Display System (IDS) and the other indicated the Low Level Windshear Alert System (LLWAS) as their preferred system for displaying textual bird threat information. Several participants voiced concern over the potential of adding a new WiSC standalone display (i.e., display monitor), arguing that they already had too many displays in the ATCT environment. Figure 24 shows the responses for WiSC system display preference.

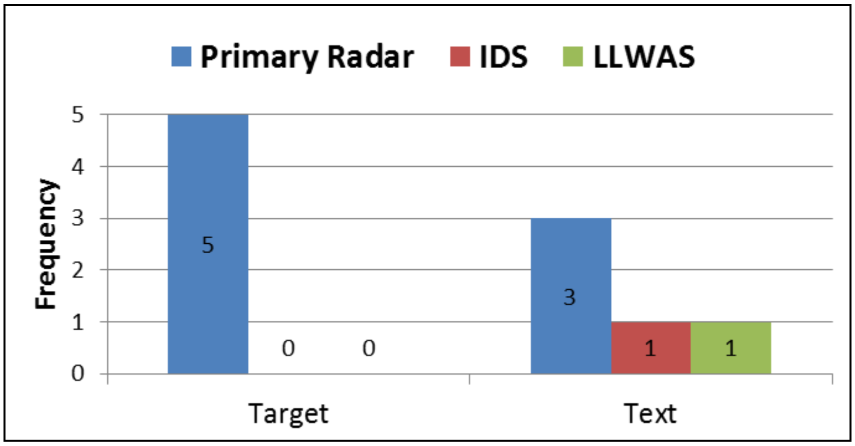


Figure 24. The WiSC Display System Preference

The WiSC Display Symbology.

The WiSC Target Symbol. Participants rated the WiSC data tag and symbol used in the target condition as acceptable. One participant noted that more should be done to make the bird position symbol look different from other aircraft position symbols because it could be confused as a "VFR popup" or airspace violator. This is of particular concern for less experienced controllers or generally when workload is high.

The WiSC Textual Representation. Participants rated the WiSC text display style acceptable. Participants indicated that they would prefer to be able to choose the location of the text box on their display as opposed to a static position, as was the case in the simulation. Also, there were suggestions that the WiSC textual representation would benefit by having a reference to direction of flight.

Color Usage. In this simulation study, color coding was used to differentiate between bird activity and significant bird activity. Although the colors selected for the simulation were generally acceptable, participants reported that they did not feel the need to differentiate between levels of bird activity. This may be a research artifact because there were no defined procedural differences in controller actions or responsibilities between the two bird threat levels in the simulation. In application, pilots would likely find the severity of the bird threat to be a critical piece of information [13].

Aural Alert. The participants were asked to rate the necessity of an aural alert for both the WiSC target and the WiSC text conditions. Participants were unanimous in their rating of essential for the WiSC text condition. Three of the five participants also rated the aural alert as essential in the target condition with the other two reporting optional and not needed. The bird threat alert used in this simulation, a 2-second bird call, was considered a good option by all participants. Participants reported that the alert was intuitive and easily distinguished from other competing aural alerts in the tower environment.

EXIT QUESTIONNAIRE AND DEBRIEFING RESPONSES.

Exit Questionnaire. This questionnaire elicited the participant's feedback on the simulation study environment, experimental conditions, and their overall opinions of WiSC. The participants felt that they were adequately trained in the simulator (*M* = 9.4, *SD* = 0.89) and on the WiSC concept (*M* = 9.6, *SD* = 0.54). Participants rated the overall value of WiSC information very high for both controllers (*M* = 9.2, *SD* = 1.09) and pilots (*M* = 9.4, *SD* = 0.89). They rated the ability of WiSC to provide better bird threat information to pilots as very high (*M* = 8.8, *SD* = 1.09). Overall, the participants were in favor of having WiSC information (*M* = 8.8, *SD* = 0.83) in the ATCT environment.

Debriefing Responses. Participant comments during the final debrief session were consistent with the results from the Interface Evaluation Questionnaire. WiSC was viewed as a valuable information source for both controllers and pilots; particularly during the WiSC target presentation, because it provided the most complete bird threat information. Participant preferences for the WiSC presentation method were driven by need/desire for detailed/precise information and the associated potential workload impact. A majority of participants favored the WiSC target and WiSC text conditions, respectively. All participants were in favor of introducing the WiSC in the ATCT.

Participants indicated that the WiSC target and WiSC text presentation methods were well designed, including one participant who stated, "I like the system [WiSC target] and support it. I also think the system is very close as-is. A tweak here and there would make this a desirable feature. Make it simple and accurate, and keep the impact on the controller as small as possible."

One participant suggested that controllers and NAS users would be best served if the WiSC interface were a hybrid of the WiSC text and WiSC target presentations. The suggestion was that the default setting for WiSC should be a textual presentation. However, controllers could take action (click, quick function key, knob function, etc.) to display additional information (WiSC targets). Because this suggestion was mentioned during the first week, the research team was able to also discuss this recommendation with the participants in the second week of the simulation study. Participants responded very favorably to this hybrid approach, indicating that it helped to mitigate potential workload concerns while providing access to the detailed information if needed.

Another important theme from the final debrief was concerns with the feasibility of the WiSC supervisor presentation. Participants did not think the WiSC supervisor presentation would work in their facilities. In some cases, the major concern was because of ATCT layout or overall size of the facility (proximity of supervisor to affected controller, overall number of operational positions, etc.). In other cases, participants were most concerned that the supervisor's workload is already high and that they have other competing duties. As a result, they believed WiSC information would be missed and not passed on most of the time. Finally, several participants stated that shared discretionary responsibility (of bird threat information) with supervisors would be detrimental in many ways, particularly due to overlapping and unclear responsibilities, and therefore would not be an acceptable long-term implementation solution for WiSC.

VOICE COMMUNICATIONS.

The RDHFL software collected PTT data for all over-the-frequency communications made during this simulation study. The data included the start and stop time for each communication, the overall duration of each communication, and the source of the communication (i.e., controller or simulation pilot). The research team reviewed the simulation audio/video recordings to identify all communications related to bird activity. They then transcribed and analyzed all communications related to bird threat information. The results of the analysis are presented in the following sections organized by total bird-related PTT transmissions, total bird-related PTT duration, and mean PTT duration for bird-related transmissions.

TOTAL BIRD-RELATED PTT TRANSMISSIONS. The research team analyzed the total frequency of all bird-related PTT communications across conditions. The analysis of the effect of condition on the total number of bird-related PTT transmissions was significant, χ^2 (3, N = 5) = 11.88, p = .008. Follow-up pairwise comparisons showed significant differences between the baseline condition and each WiSC condition, z = 2.03, p = .042. In addition, there was a statistically significant difference between the WiSC target and WiSC text conditions, z = 2.03, p = .042. All other comparisons were nonsignificant. Figure 25 shows the mean and standard deviation in each condition for the total bird-related PTT transmissions across conditions.

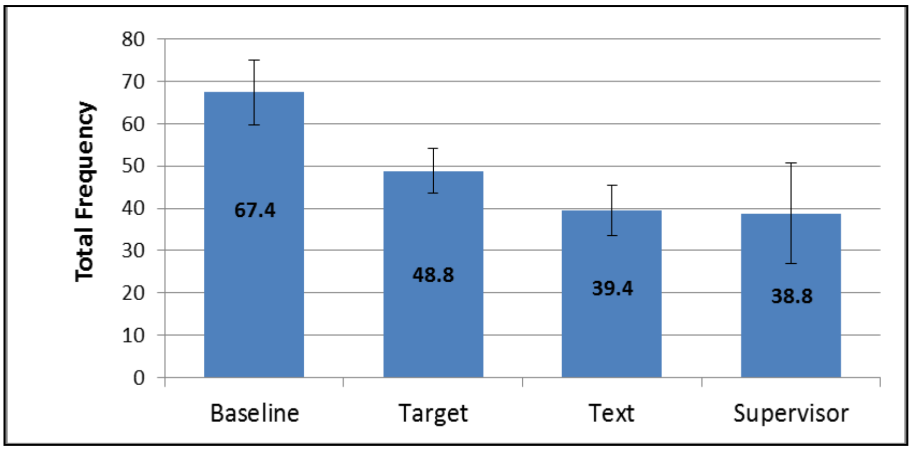


Figure 25. Total Bird-Related PTT Transmissions

The results clearly demonstrate that controllers made significantly more bird-related PTT communications during the baseline scenarios compared to the WiSC scenarios. The baseline condition required that participants report bird threat activity for 15 minutes or until they determined that the birds were no longer a factor. Therefore, in the baseline condition, participants were likely to verbally query subsequent aircraft pilots regarding previously reported bird activity. In contrast, WiSC conditions provided current and precise information regarding bird threats and relieved participants of both the 15-minute reporting period and the need to query subsequent aircraft for updated bird threat information.

There was also a statistically significant difference between the WiSC target and WiSC text conditions with regard to total bird-related PTT transmissions. Participants made more PTT transmissions on average in the WiSC target condition than in the WiSC text condition. The most likely explanation for this difference is due to the more precise position information found in the WiSC target condition. Because additional bird threat position updates were available during the WiSC target condition, the participants were able to provide pilots with the most current information as it became available, resulting in more transmissions. Even so, they made fewer transmissions with the more precise information than when following current ATC procedures in the baseline condition.

TOTAL BIRD-RELATED PTT DURATION. The research team analyzed the total duration of all bird-related PTT communications across conditions. The analysis of the effect of condition on the total duration of bird-related PTT transmissions was significant, χ^2 (3, N = 5) = 12.120, p = .007. Follow-up pairwise comparisons showed significant differences between the baseline condition and the WiSC text and WiSC supervisor conditions, z = 2.02, p = .043. There were also significant differences between the WiSC target condition and the WiSC text and supervisor conditions, z = 2.02, p = .043. All other comparisons were nonsignificant. Figure 26 shows the mean and standard deviation in each condition for the total bird-related PTT transmissions across conditions.

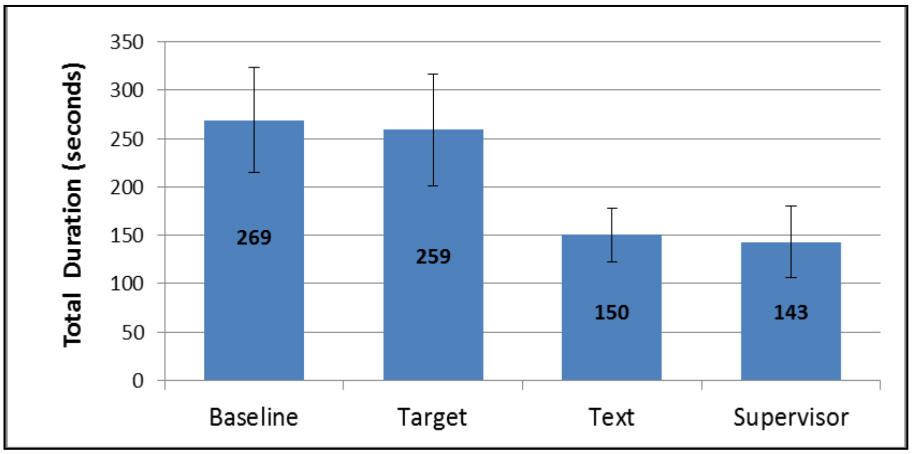


Figure 26. Total Bird-Related PTT Duration

The results demonstrate that the total duration of bird-related PTT transmissions was highest in the baseline condition followed by the WiSC target condition. This may be explained using similar explanations observed in the preceding analysis. For example, the baseline condition required more bird threat-related communications to satisfy procedural requirements (i.e., 15-minute reporting period) and to gather updated information from subsequent pilots. The WiSC target condition afforded more opportunities to communicate updated bird threat position information than the WiSC text and WiSC supervisor conditions and therefore had a higher total PTT duration. In addition, the phraseology (and quantity of information passed) in the WiSC target condition was considerably greater than in the other WiSC conditions and therefore was necessarily more time-consuming.

MEAN BIRD-RELATED PTT DURATION. The research team analyzed the PTT duration for bird-related PTT communications across conditions. The analysis of the effect of condition on the total number of bird-related PTT transmissions was nonsignificant, χ^2 (3, N = 5) = 2.52, p = .472. Figure 27 shows the mean and standard deviation in each condition for PTT duration.

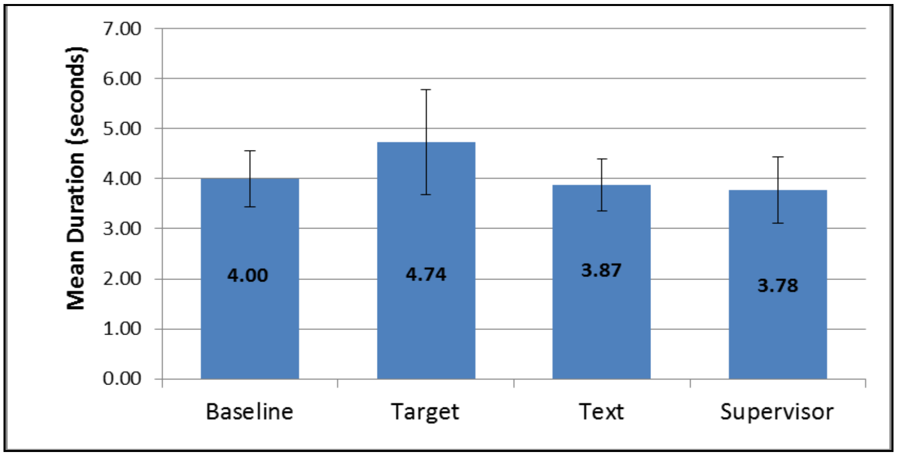


Figure 27. Mean Duration of Bird-Related PTT Transmissions

While the analysis of mean duration of bird-related PTT transmission did not yield significance, it was noted that the mean duration was highest in the WiSC target condition, followed by the baseline condition. These findings are consistent with the preceding analyses in that, while the WiSC target condition contains increased information, there does not appear to be a statistically significant difference (cost) associated. This is further supported by the previous analysis of total bird-related PTT transmissions (see figure 25) where there were significantly fewer total bird-related PTT transmissions found in the WiSC target condition than in the baseline condition. Therefore, it is believed that the slight increase in mean duration of PTT transmissions in the WiSC target condition is offset by significantly fewer overall bird-related PTT communications.

AIR TRAFFIC WORKLOAD INPUT TECHNIQUE.

The research team used the WAK to collect the participant's subjective workload ratings. The WAK interval was set to 5 minutes, with a 10-second time-out period. If participants were not able to respond to the prompt, this was coded as missing data. There were 11 missing ratings out of 160 opportunities (6.8%). These missing values were substituted with the condition mean to afford statistical analysis. The WAK ratings were on a 10-point scale.

The research team analyzed the effect of condition on subjective ATWIT workload ratings. The analysis was statistically nonsignificant, χ^2 (3, N = 5) = 4.71, p = .19. Although a statistical difference between the four experimental conditions could not be detected, the workload ratings were higher in the baseline condition than in the WiSC conditions. Figure 28 shows the mean and standard deviation of the ATWIT workload ratings by condition.

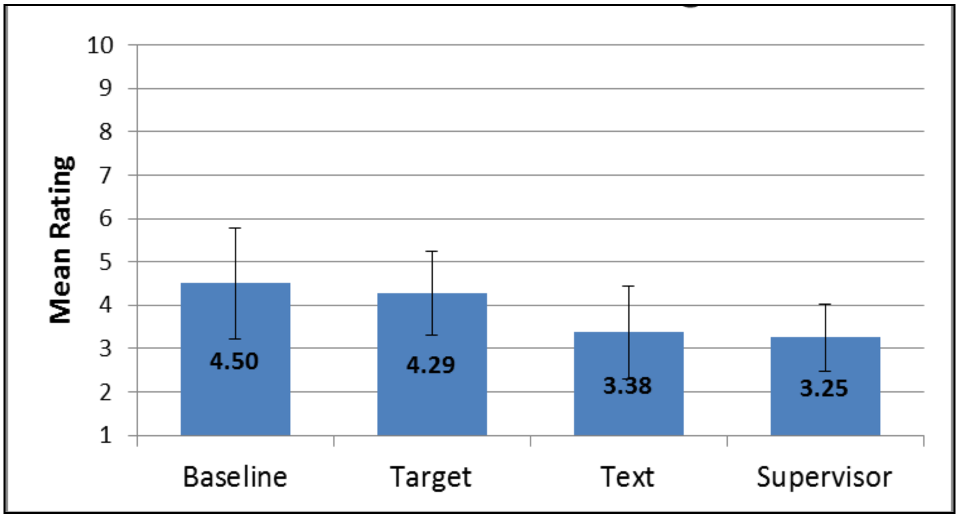


Figure 28. The ATWIT Workload Ratings

<u>OBSERVER RATING FORM</u>.

The purpose of the ORF was to obtain an over-the-shoulder subjective rating of participant performance using an experienced ATC SME evaluator. Observer ratings were based on a 5-point scale. Table 4 displays the means for each overall ORF rating category by condition as well as the Friedman test statistic and associated *p*-values. All tests of the effect of condition on overall ORF ratings were statistically nonsignificant.

Table 4. Observer Rating Form Responses

ORF Question*	Baseline	Target	Text	Supervisor	χ^2	*p*-value
Overall safe and efficient traffic flow	3	2.6	3.4	3.4	5.28	.15
Overall attention and situation awareness	3.2	3	3.6	3.2	4.39	.22
Overall prioritizing	3.2	3	3.4	3.4	3.00	.39
Overall providing control information	3	3	3	3.2	3.00	.39
Overall communicating	3.4	3.2	3.4	3.2	0.857	.84
Overall bird information handling	3.4	2.8	3.4	3	6.23	.11

*ORF ratings based on a 5-point scale.

CONCLUSIONS

Participants in this study were unanimously in favor of receiving more accurate and current bird threat information and considered the presentation methods demonstrated in this simulation to be a good first step. The Wildlife Surveillance Concept (WiSC) target and WiSC text presentation methods were preferred by participants in both objective and subjective simulation measures of preference and performance. WiSC was viewed as a major improvement over current-day operational methods of detecting bird threats that rely on direct human observation.

THE WiSC DISPLAY PREFERENCES.

Most participants favored the WiSC target presentation due to the precise nature of the position data it provided. All participants agreed that the WiSC target presentation provided the most complete and precise information to distribute to pilots. The WiSC text presentation was also rated very highly across all participants, with some participants preferring this method due to the ease of interpreting the bird threat information displayed. Participants least liked the WiSC supervisor presentation method due to real-world implementation concerns (physical Airport Traffic Control Tower (ATCT) layout, supervisor workload, problems sharing discretionary responsibility, etc.).

The participants reported that the controller should be solely responsible for the management and dissemination of bird threat information (as opposed to the supervisor) and therefore recommended that WiSC information be displayed at their position. Specifically, participants favored the tower primary radar display system for the location of WiSC information. For the WiSC target case, participants were unanimous in this preference. In the WiSC text condition, participants still favored the primary radar display with alternative suggestions, such as the Information Display System and Low Level Windshear Alert System.

OPERATIONAL IMPLICATIONS.

The key operational consideration was controller workload. For some participants, there was a reported tradeoff between bird threat information quality (precision, specificity, completeness, usefulness, etc.) and potential workload implications. Although the WiSC target condition presented the most complete bird threat information, for some, it may also have required significantly more cognitive effort to process and apply the information. In contrast, some participants reported that information in the WiSC text condition was much more user-friendly, but at the expense of more precise and detailed threat position information.

Some simulation data suggested marginal impacts to workload in the WiSC target condition compared to the WiSC text and WiSC supervisor conditions. However, this was not consistent across the various dimensions of workload probed in this simulation study (impact, overall Post Scenario Questionnaire (PSQ) workload rating, Air Traffic Workload Input Technique (ATWIT), perceived number of bird events, etc.). For example, the PSQ workload responses and ATWIT workload ratings did not show significant statistical differences between WiSC conditions. Where marginal workload impacts were observed (e.g., WiSC impact on workload PSQ item), the overall WiSC target workload ratings were still considered in the moderate rating range. The aggregate data do not suggest a significant impact to controller workload between the

WiSC target condition and the WiSC text or WiSC supervisor conditions. In contrast, there were higher workload ratings for the baseline (pilot reports (PIREPS)) condition when compared to the WiSC target and text conditions. In fact, the baseline (PIREPS) condition was rated significantly more negatively in terms of workload, impact of birds on the scenario, and even the overall number of perceived bird threats in the scenario.

One of the most significant benefits of WiSC was the positive impact that it had on bird-related push-to-talk (PTT) communications. There was a reduction in both the total number and total duration of bird-related PTT transmissions in WiSC conditions compared to the baseline condition. While the WiSC target condition represented a significant improvement to the baseline condition, the greatest reduction in bird-related PTT transmissions was observed in the WiSC text and WiSC supervisor conditions. The results and conclusions of the PTT analysis mirrored those observed in the discussion of workload. While there is an underlying cost associated with more detailed bird threat information provided in the WiSC target condition (compared to WiSC text and supervisor conditions), there is significant improvement over baseline conditions. The overall results of the PTT communications analysis are particularly encouraging because previous research identified increased communications, and the resultant impact on controller workload, as amongst the greatest potential risks to implementing bird radar in the ATCT.

The simulation resulted in a potential solution to the tradeoff between information precision/quality and potential workload impact. The recommendation is to employ a hybrid approach with textual presentation of bird threats as the default. If the controllers required additional detailed information, they could access a format similar to that used during the WiSC target condition. In this way, when workload is low, controllers could elect to receive and share the most precise information using the target format. As their workload increased, they could opt to receive less information provided by the WiSC text mode. This approach would be consistent with how weather information is currently handled in the ATCT. If implemented in this fashion, WiSC could serve a full range of operational conditions while providing the most substantial improvements to bird threat information quality.

FUTURE WORK

The concept and technology encompassed by WiSC could be matured through a combination of field and simulation activities. Providing avian radar at an airport and capturing pre- and post-deployment metrics with airport operations and air traffic control representatives could be a substantial step in demonstrating the benefits of WiSC. In addition, the outcomes of this simulation suggest several new WiSC research questions. More work could be conducted to examine “blanket broadcasting” of radar-derived bird threat information. By nature, these broadcasts would be less specific and likely less workload intensive. The research team also suggests that the hybrid text-target approach be examined to assess participant opinions and performance in the laboratory. This evaluation would help to further develop and define bird threat information requirements. Finally, more laboratory work could be done to examine the effect that WiSC may have at different air traffic levels.

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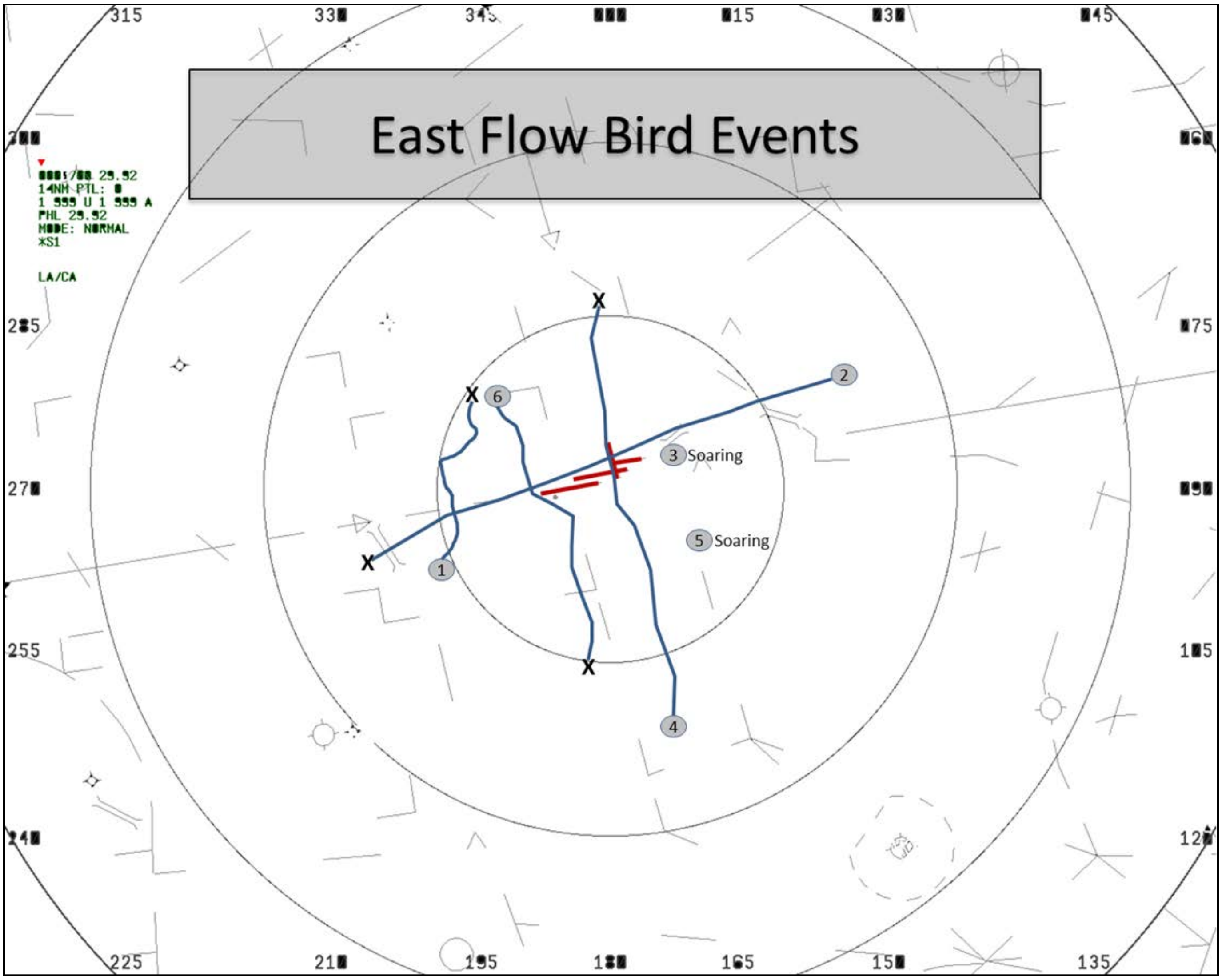
APPENDIX A—BIRD EVENT DESCRIPTIONS

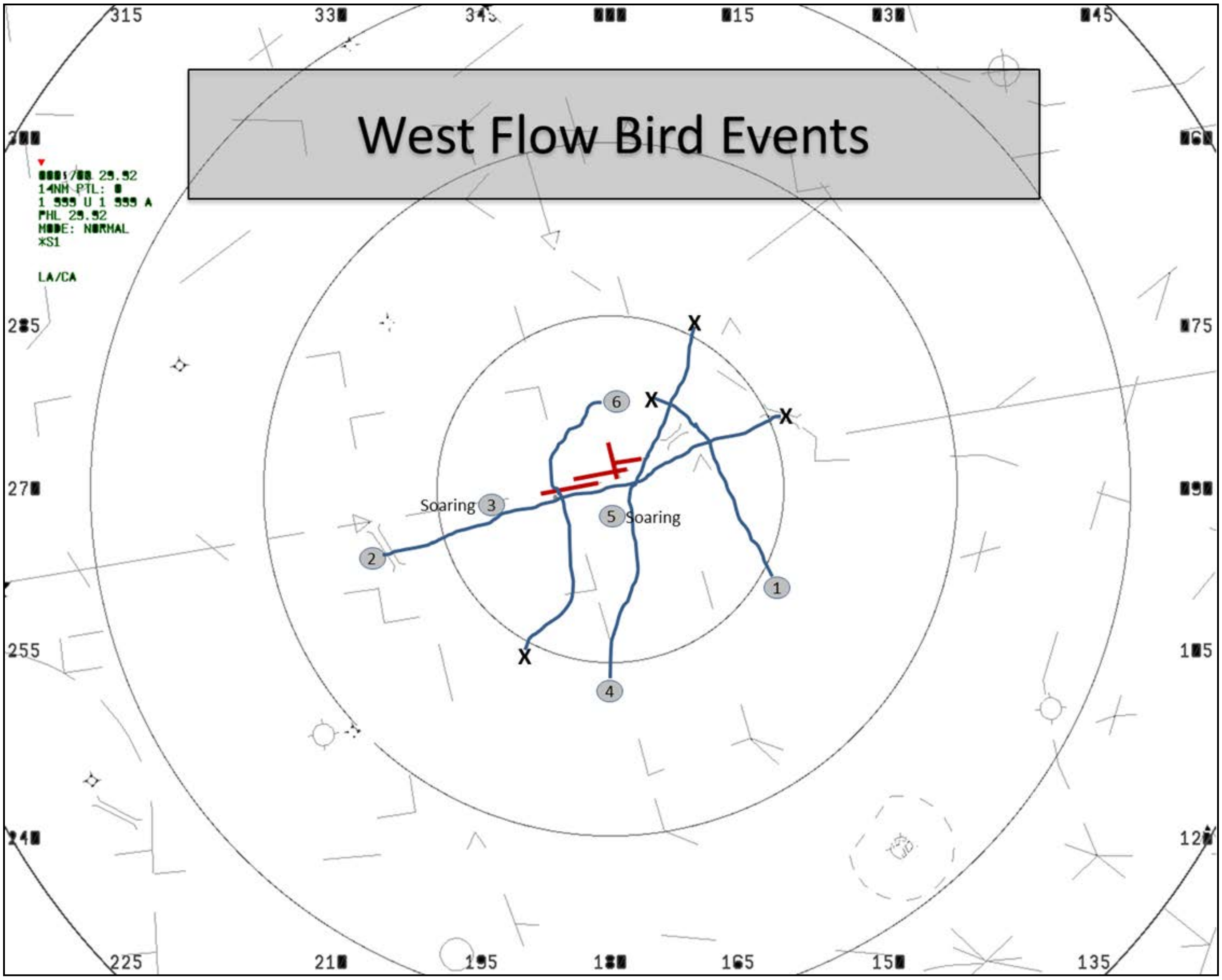
East Flow Bird Events

Event #	Description	Main ATC Impact	Bird Path	Threat Level	Altitude (feet)	Speed (mph)	Duration (minutes)	Start Time (minutes)	End Time (minutes)
1	Birds cross 9R arrival at 900 ft. Birds descend and land at the sanctuary.	Arrival	Straight	Normal	900	25	8	4	12
2	Birds are a threat east-west along 9L departure course then out the 9R arrival course. Impact is more persistent on arrival path.	Departure /Arrival	Straight	Significant	500	40	20	10	30
3	Bird threat affects runway 9L, 1 mile East/Southeast departure end. Threat duration is 5 minutes then birds proceed north.	Departure	Soaring	Significant	800	20 (soaring)	5	10	15
4	Bird threat is present 3/4 miles down 9L runway at about 600 feet crossing south-north. This threat also impacts 35 arrivals.	Departure /Arrival	Straight	Normal	600	45	15	12	27
5	Birds present runway 35, two mile final 600-700 feet on or near approach course. Bird threat is soaring and persistent for 20 minutes then movies out of scenario.	Arrival	Soaring	Significant	650	20 (soaring)	20	15	35
6	Birds from event #1 return over arrival path.	Arrival	Straight	Significant	300	30	10	30	40


East Flow Bird Events
3 Soaring
5 Soaring
1
2
4
6

West Flow Bird Events

Event #	Description	Main ATC Impact	Bird Path	Threat Level	Altitude (feet)	Speed (mph)	Duration (minutes)	Start Time (minutes)	End Time (minutes)
1	Birds cross arrival runway at 900 feet then descend near the Schuylkill River.	Arrival	Straight	Normal	900	25	8	4	12
2	Bird threat west-east along 27L departure course then over the field and out the arrival course. The impact of the birds is more persistent on the departure path.	Departure /Arrival	Straight	Significant	600	40	20	10	30
3	Birds are near runway 27L, 1 mile west of departure end and slightly north of departure course. Threat duration is 5 minutes then the birds proceed north and descend into sanctuary.	Departure	Soaring/ Circling	Significant	1000	20 (soaring)	5	10	15
4	Birds are transitioning south to north, along runway 35 final then turning slightly northeast to cross RWY 27R approach course on about a one mile final.	Arrival	Straight	Normal	300	45	15	12	27
5	Bird threat present runway 35, 1 mile final at 400 feet. Threat is just west of approach course and is soaring and persistent for 20 minutes. Birds then descend to ground, south bank of Delaware River.	Arrival	Soaring/ Circling	Significant	400	20 (soaring)	20	15	35
6	Birds return from event #1 over 27L departure runway.	Departure	Straight	Significant	500	35	10	28	40


West Flow Bird Events
Soaring
3
Soaring
5
1
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X
X
X
X

APPENDIX B—INFORMED CONSENT STATEMENT

I, ________________________________, understand that this assessment, entitled "Wildlife Surveillance Concept Human-in-the-Loop Laboratory Demonstration" is sponsored by the Federal Aviation Administration (FAA).

Nature and Purpose:
I have been recruited to volunteer as a participant in this evaluation. The purpose of the evaluation is to elicit information from current Certified Professional Controllers (CPCs) regarding several notional approaches at providing supplemental avian threat information directly to the Airport Traffic Control Tower (ATCT). The data collected will help to identify and shape future concept development and validation activities for the concept.

Experimental Procedures:
Two groups of three CPCs will participate in this demonstration from March 16th 2015 through March 27th 2015. The first group of three CPCs will participate week one, while the second will participate in week two. The demonstration will take place at the Research Development Human Factors Laboratory (RDHFL) which is located at the FAA William J. Hughes Technical Center in Atlantic City, NJ.

On the first day, participants will arrive at the demonstration location and be briefed by the research team on the nature and purpose of the activities, as well as participant roles, responsibilities, and expectations. Participants will be given airspace training and participate in several training runs in the simulator.

On the second and third days, the participants will be exposed to several different experimental research conditions. In these research conditions we will manipulate the method of delivering supplemental avian hazard information. Participants will be asked to complete questionnaires and participate in discussions after each experimental session. On the final day, participants will be debriefed and participate in a group discussion.

Audio and Video Recording of Simulation and Discussions:
I understand that, with my consent, simulation runs and group discussion sessions will be recorded for the sole purposes of data analysis. I understand that this data will remain strictly confidential and I will not be identified in any way on the recording. In addition, I am assured that the recordings will never be used for any other purposes than originally intended and that the recordings will be appropriately archived or destroyed following the activity.

Discomfort and Risks:
I understand that I will not be exposed to any foreseeable risks. The work that I will perform in the study is safe and consists of participating in an Airport Traffic Control Tower (ATCT) simulator, completing questionnaires, listening to presentations, and providing feedback to the researchers about my experience during the sessions.

Confidentiality:
My participation is strictly confidential, and no individual names or identities will be recorded or released in any reports.

Benefits:
I understand that the only benefit to me is that I will be able to provide the researchers with valuable feedback and insight regarding my experiences during the research activity. My data will help the FAA to understand the most effective method for presenting enhanced avian threat information to the ATCT.

Participant Responsibilities:
I am aware that to participate in this study I must be identified as a current Certified Professional Controller who is qualified at an Air Traffic Control Facility. I will answer any questions asked during the assessment to the best of my abilities. I will not discuss the content of the experiment with anyone until the study is completed.

Participant's Assurances:
I understand that my participation in this study is completely voluntary, and I have the freedom to withdraw at any time without penalty. I also understand that the researchers in this study may terminate my participation if they feel this to be in my best interest. I have not given up any of my legal rights or released any individual or institution from liability for negligence.

The WiSC research team has adequately answered all the questions I have asked about this study. I understand that individuals from the assessment team will be available to answer any other questions that I may have as the study proceeds.

If I have questions about this study or need to report any adverse effects from the research procedures, I will contact the Mark Hale at 609-485-7562.

Compensation and Injury:
I agree to immediately report any injury or suspected adverse effect to the assessment team conducting this research. Local clinics and hospitals will provide any treatment, if necessary. I agree to provide, if requested, copies of all insurance and medical records arising from any such care for injuries/medical problems.

Signature Lines:
I have read this informed consent statement. I understand its contents, and I freely consent to participate in this study under the conditions described. I understand that, if I want to, I may have a copy of this statement.

Research Participant:____ Date:__________
Witness:____ Date:__________

APPENDIX C—BACKGROUND INFORMATION QUESTIONNAIRE

Background Information Questionnaire

Instructions:
This questionnaire is designed to obtain information about your background and experience as a Certified Professional Controller (CPC) in the civil air traffic control environment. Researchers will only use this information to describe the participants in this study as a group. Your identity will remain anonymous.

1. How long have you been an Air Traffic Controller?	_____ years _____ months

2. How long have you actively controlled traffic in the tower cab environment?	_____ years _____ months

3. How long have you actively controlled traffic in the terminal radar environment?	_____ years _____ months

4. When did you last control traffic?	(mm/yyyy) ____________

5. Please identify the shift(s) that you work a majority of time.	___Day ___ Night ___ Both

6. Please list the facilities that you have controlled traffic at.

____
____
____
____

7. Please list any other things that you would like us to know about your background.

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Pre- Simulation Opinion Questionnaire

Instructions:
This questionnaire is designed to obtain information about your opinions regarding bird threats in your current operational environment. These are your opinions. Researchers will only use this information to describe the participants in this study as a group. Your identity will remain anonymous.

1. Please rate your awareness of the extent of bird strikes in the ATC environment.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

Comments:

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____

____

2. Please rate your awareness of current avian radar research in Airport Operations or ATC.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

Comments:

____

____

____

3. Bird hazards play a significant role in my daily activities at my facility.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

Please explain:

____

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4. Reporting bird hazards at my facility contributes significantly to my duties/workload.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

Comments:

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5. How often do birds *impact* your facility?	Typical Days: ____ times per day/week/month Peak Season: ____ times per day/week/month

6. How often do you issue *bird threat advisories*?	Typical Day: ____ times per day/week/month Peak Season: ____ times per day/week/month

7. Which of the following operational impacts of bird threats have you experienced as a controller (check all that apply)	___ Pilot request to delay departure ___ Aborted landing ___ Precautionary landing ___ Emergency landing ___ Other _________________

8. The inaccurate/imprecise nature of current bird information increases my workload.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

Comments:

____

____

____

9. Precise and timely bird threat information would be valuable to a controller in the ATC environment.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

Please explain:

____

____

____

10. I am in favor of having additional bird information available to me.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

Please explain:

____

____

____

11. Additional information regarding your opinion of bird hazards in the ATC environment:

____

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Post Scenario Questionnaire – Baseline

Instructions:
Please answer the following questions based upon your experience in the scenario just completed. Your identity will remain anonymous.

Post Scenario Questionnaire – Baseline			
1. Please rate the *ATC realism* of this scenario?	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
2. Please rate the *realism of simulation pilots*.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
3. Please rate the *realism* of *simulated PIREPS*.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
4. Please rate your *overall workload* throughout the scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
5. Please rate the *contribution of birds* to your *overall workload*.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
6. Please rate the impact that managing bird activity had on your *ATC situational awareness* during this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

	Much Lower	Lower	About the Same	Higher	Much Higher
7. Please rate your *time spent looking at the radar display* in this scenario compared to working at your facility.	①②	③④	⑤⑥	⑦⑧	⑨⑩

8. How did you keep track of PIREPS and bird threat location in the Baseline condition?	___ Kept notes paper ___ Kept info in memory ___ Other ________________

	Much Lower	Lower	About the Same	Higher	Much Higher
9. Please rate the *number* of bird events in this scenario compared to an *average day* at your facility.	①②	③④	⑤⑥	⑦⑧	⑨⑩

Comments:

10. Please list any additional thoughts you have regarding the scenario you've just completed.

Post Scenario Questionnaire – WiSC Target

Instructions:
Please answer the following questions based upon your experience in the scenario just completed. Your identity will remain anonymous.

Post Scenario Questionnaire – Scenario Items

1. Please rate the ATC realism of this scenario?	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
2. Please rate the realism of simulation pilots.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
3. Please rate your overall workload throughout the scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
4. Please rate the contribution of birds to your overall workload.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

	Much Lower	Lower	About the Same	Higher	Much Higher
5. Please rate the *number* of bird events in this scenario compared to an *average day* at your facility.	①②	③④	⑤⑥	⑦⑧	⑨⑩

Comments:

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Post Scenario Questionnaire – Supplemental Bird Threat Information

6. Please rate the *value* of supplemental bird threat information in this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
7. Please rate the impact that supplemental bird threat information had on your *workload* during this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
8. Please rate the impact that managing bird activity had on your *ATC situational awareness* during this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

	Much Lower	Lower	About the Same	Higher	Much Higher
9. Please rate your perception of the *time spent looking at the radar display* during this scenario compared to working at your facility.	①②	③④	⑤⑥	⑦⑧	⑨⑩

Post Scenario Questionnaire – WiSC Target Evaluation			
10. The WiSC target symbol presentation was *useful*.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
11. The WiSC target symbol presentation was *easy to understand.*	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
12. The WiSC target symbol presentation contained all the information required to provide advisories to pilots.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
13. The WiSC target symbol was easy to see and interpret (size, color, etc.).	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

14. Please list the things you *liked* about the WiSC target symbol used in this scenario.

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15. Please list the things you *did not like* about the WiSC target symbol used in this scenario. What changes would you suggest to address these issues?

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16. Please list any additional thoughts you have regarding the scenario you've just completed.

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Post Scenario Questionnaire – WiSC Text

Instructions:
Please answer the following questions based upon your experience in the scenario just completed. Your identity will remain anonymous.

Post Scenario Questionnaire – Scenario Items			
1. Please rate the ATC realism of this scenario?	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
2. Please rate the realism of simulation pilots.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
3. Please rate your overall workload throughout the scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
4. Please rate the contribution of birds to your overall workload.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

	Much Lower	Lower	About the Same	Higher	Much Higher
5. Please rate the *number* of bird events in this scenario compared to an *average day* at your facility.	①②	③④	⑤⑥	⑦⑧	⑨⑩

Comments:

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Post Scenario Questionnaire – Supplemental Bird Threat Information			
6. Please rate the *value* of supplemental bird threat information in this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
7. Please rate the impact that supplemental bird threat information had on your *workload* during this scenario	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
8. Please rate the impact that managing bird activity had on your *ATC situational awareness* during this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

	Much Lower	Lower	About the Same	Higher	Much Higher
9. Please rate your perception of the *time spent looking at the radar display* during this scenario compared to working at your facility.	①②	③④	⑤⑥	⑦⑧	⑨⑩

Post Scenario Questionnaire – WiSC Text Box Evaluation			
10. The WiSC text box presentation was useful.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
11. The WiSC text box presentation was easy to understand	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
12. The WiSC text box presentation contained all the information required to provide advisories to pilots.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
13. The WiSC text *aural alert* was *useful* to discriminate new bird information.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
14. The WiSC text *flashing* was *useful* to discriminate new bird information.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
15. The sound used for the aural alert was acceptable in the simulation environment.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

16. Which of the methods for alerting new bird information would be preferred if WiSC text information was implemented in the field?	___ Flashing text ___ Aural alert ___ Both

17. Please list the things you *liked* about the WiSC text box used in this scenario.

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18. Please list the things you *did not like* about the WiSC text box symbol used in this scenario. What changes would you suggest to address these issues?

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19. Please list any additional thoughts you have regarding the scenario you've just completed.

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Post Scenario Questionnaire – WiSC Supervisor

Instructions:
Please answer the following questions based upon your experience in the scenario just completed. Your identity will remain anonymous.

Post Scenario Questionnaire – Scenario Items			
1. Please rate the ATC realism of this scenario?	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
2. Please rate the realism of simulation pilots.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
3. Please rate your overall workload throughout the scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
4. Please rate the contribution of birds to your overall workload.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

5. Please rate the *number* of bird events in this scenario compared to an *average day* at your facility.	Much Lower	Lower	About the Same	Higher	Much Higher
	①②	③④	⑤⑥	⑦⑧	⑨⑩

Comments:

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Post Scenario Questionnaire – Supplemental Bird Threat Information			
6. Please rate the *value* of supplemental bird threat information in this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
7. Please rate the impact that supplemental bird threat information had on your *workload* during this scenario	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High
8. Please rate the impact that managing bird activity had on your *ATC situational awareness* during this scenario.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

9. Please rate your perception of the *time spent looking at the radar display* during this scenario compared to working at your facility.	Much Lower	Lower	About the Same	Higher	Much Higher
	①②	③④	⑤⑥	⑦⑧	⑨⑩

Post Scenario Questionnaire – WiSC Supervisor			
10. The WiSC information provided by the supervisor was useful.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
11. The WiSC information provided by the supervisor was easy to understand.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree
12. The WiSC information provided by the supervisor contained all the information required to provide advisories to pilots.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

13. Please list the things you *liked* about the WiSC supervisor presentation used in this scenario.

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14. Please list the things you *did not like* about the WiSC supervisor presentation used in this scenario. What changes would you suggest to address these issues?

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15. Please list any additional thoughts you have regarding the scenario you've just completed.

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APPENDIX F—WILDLIFE SURVEILLANCE CONCEPT INTERFACE EVALUATION QUESTIONNAIRE

WiSC Interface Evaluation Questionnaire

Instructions:
Please answer the following questions based on your opinion of the interface options presented in the simulation. Your identity will remain anonymous.

1. Which bird threat presentation method did you *most prefer*?	___ WiSC Target ___ WiSC Text Box ___ Supervisor Presentation

Please explain why you preferred this method most.

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2. Which bird threat presentation method did you *least prefer*?	___ WiSC Target ___ WiSC Text Box ___ Supervisor Presentation

Please explain why you preferred this method least. Please include any suggestions for how to improve this presentation method if applicable.

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	Target	**Text**
3. Where should WiSC information be displayed if presented directly to controllers? (please answer for each condition)	___ Tower Radar ___ IDS ___ ASDE-X ___ LLWAS ___ New display ___ Other	___ Tower Radar ___ IDS ___ ASDE-X ___ LLWAS ___ New display ___ Other

If other, please explain:

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4. Please rate the *importance* of a WiSC *aural alert* in each condition.	**Target Condition**	**Text Condition**
	__ Not needed (no benefit) __ Optional (some benefit) __ Essential (major benefit	__ Not needed (no benefit) __ Optional (some benefit) __ Essential (major benefit)

Comments

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5. What type of information regarding bird activity would be useful to you? (check all that apply)	____ Location only ____ Heading ____ Altitude ____ Species ____ Biomass ____ All available ____ Other: ________________

6a. Please rate *time spent looking at the radar display* during the WiSC Target condition compared to the Baseline (PIREPS) condition.	Much Lower	Lower	About the Same	Higher	Much Higher
	①②	③④	⑤⑥	⑦⑧	⑨⑩

6b. Please rate *time spent looking at the radar display* during the WiSC Text condition compared to the Baseline (PIREPS) condition.	Much Lower	Lower	About the Same	Higher	Much Higher
	①②	③④	⑤⑥	⑦⑧	⑨⑩

6c. Please rate *time spent looking at the radar display* during the WiSC Supervisor condition compared to the Baseline (PIREPS) condition.	Much Lower	Lower	About the Same	Higher	Much Higher
	①②	③④	⑤⑥	⑦⑧	⑨⑩

7. Who should be the *initial recipient* of bird threat information? (select one)	________ Direct to controller ________ Direct to supervisor, passed to controller ________Severe threats go direct to controller, all others to supervisor

8. Do you have any additional comments that you have regarding your ideal interface for enhanced bird threat information (e.g., who, what, where, or when)?

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Exit Questionnaire

Instructions:
Please answer the following questions based upon your experience in the during this activity and your opinions on the material covered. Your identity will remain anonymous.

1. Training was sufficient on *airspace operations*, *simulator equipment*, and the *simulation environment* to allow me to participate in this study.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

2. Training was sufficient on the *background* and *purpose* of WiSC for me to participate in this study.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

3a. Please rate the impact that WiSC had on passing *improved* bird threat info to pilots.	Extremely Low	①②③④⑤⑥⑦⑧⑨⑩	Extremely High

3b. Which WiSC condition allowed you to pass the best information to pilots? (circle one)	Target	Text	Supervisor	About the Same (all)

4. Additional bird threat information would be *valuable* for a pilot.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

5. Additional bird threat information would be *valuable* for a controller in the ATC environment.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

6. I am in favor of having additional bird information available to me in the ATC environment.	Strongly Disagree	①②③④⑤⑥⑦⑧⑨⑩	Strongly Agree

7. Has your opinion on the introduction of supplemental avian threat information to the ATC environment *changed* during this activity? If so, please explain how:

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8. Were there any instances where you chose <u>not to issue an advisory</u> even when notified of a threat by WiSC?	Yes	No

If yes, please explain the rationale behind these decisions:

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9. What were the motivating/contributing factors in the decision to issue bird advisory information to aircraft during the simulation? (e.g., proximity to aircraft, altitude of birds, direction of birds, etc.)

Please explain:

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10. Do you have any additional comments related to the Wildlife Surveillance Concept or the introduction of supplemental bird threat information to the ATC environment?

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APPENDIX H—OBSERVER RATING FORM

Instructions

This form is designed to be used by supervisory air traffic control specialists (SATCSs) to evaluate the effectiveness of controllers working in simulation environments. SATCSs will observe and rate the performance of controllers in several different performance dimensions using the scale below as a general purpose guide. Use the entire scale range as much as possible. Take extensive notes on what you see. Do not depend on your memory. Write down your observations. Space is provided after each scale for comments. You may make preliminary ratings during the course of the scenario. However, wait until the scenario is finished before making your final ratings and remain flexible until the end when you have had an opportunity to see all the available behavior. At all times please focus on what you actually see and hear. This includes what the controller does and what you might reasonably infer from the actions of the pilots. If you do not observe relevant behavior or the results of that behavior, then you may leave a specific rating blank. Also, please write down any comments that may help improve this evaluation form. Do not write your name on the form itself. You will not be identified by name. An observer code known only to yourself and the researchers conducting this study will be assigned to you. The observations you make do not need to be restricted to the performance areas covered in this form and may include other areas that you think are important.

Assumptions

ATC is a complex activity that contains both observable and unobservable behavior. There are so many complex behaviors involved that no observational rating form can cover everything. A sample of the behaviors is the best that can be achieved, and a good form focuses on those behaviors that controllers themselves have identified as the most relevant in terms of their overall performance. Most controller performance is at or above the minimum standards regarding safety and efficiency. The goal of the rating system is to differentiate performance above this minimum. The lowest rating should be assigned for meeting minimum standards and also for anything below the minimum since this should be a rare event. It is important for the observer/rater to feel comfortable using the entire scale and to understand that all ratings should be based on behavior that is actually observed.

Remove this Page and keep it available while doing ratings

Scale	Quality	Supplementary
1	**Unsatisfactory**	Does not complete required tasks, Indecisive, Inefficient, Disorganized, Numerous major and minor mistakes, Not acceptable performance
2	**Deficient**	Completes most required tasks, Inefficient, Some disorganization, Numerous minor mistakes, few major mistakes, Not acceptable performance
3	**Satisfactory**	Completes all necessary tasks, some inefficiency or disorganization, No major mistakes, some minor mistakes, acceptable performance
4	**Very Good**	Completes all necessary tasks, Mostly efficient and organized, No major mistakes, very few minor mistakes, acceptable performance
5	**Outstanding**	Completes all necessary tasks, Efficient and organized, No major or minor mistakes, Solves all problems, Plans well, Performance is exceptional

I - MAINTAINING SAFE AND EFFICIENT TRAFFIC FLOW
II - MAINTAINING ATTENTION AND SITUATION AWARENESS
III – PRIORITIZING
IV – PROVIDING CONTROL INFORMATION
V – COMMUNICATING
VI – BIRD THREAT INFORMATION HANDLING - BASELINE
VII – BIRD THREAT INFORMATION HANDLING - WISC

I - Maintaining Safe and Efficient Traffic Flow	
1. Maintaining Separation and Resolving Potential Conflicts .... • using control instructions that maintain appropriate aircraft and airspace separation • detecting and resolving impending conflicts early • recognizing the need for speed restrictions and wake turbulence separation	**1 2 3 4 5**
2. Sequencing Aircraft Efficiently .... • using efficient and orderly spacing techniques for arrival, departure, and en route aircraft • maintaining safe arrival and departure intervals that minimize delays	**1 2 3 4 5**
3. Using Control Instructions Effectively/Efficiently .... • providing accurate navigational assistance to pilots • issuing economical clearances that result in need for few additional instructions to handle aircraft completely • ensuring clearances require minimum necessary flight path changes	**1 2 3 4 5**
4. Overall Safe and Efficient Traffic Flow Scale Rating	**1 2 3 4 5**

II - Maintaining Attention and Situation Awareness	
5. Maintaining Awareness of Aircraft Positions .... • avoiding fixation on one area of the radar scope when other areas need attention • using scanning patterns that monitor all aircraft on the radar scope	**1 2 3 4 5**
6. Ensuring Positive Control .... • tailoring control actions to situation • using effective procedures for handling heavy, emergency, and unusual traffic situations	**1 2 3 4 5**
7. Detecting Pilot Deviations from Control Instructions .... • ensuring that pilots follow assigned clearances correctly • correcting pilot deviations in a timely manner	**1 2 3 4 5**
8. Correcting Own Errors in a Timely Manner .... • acting quickly to correct errors • changing an issued clearance when necessary to expedite traffic flow	**1 2 3 4 5**
9. Overall Attention and Situation Awareness Scale Rating..........	**1 2 3 4 5**

III – PRIORITIZING	
10. Taking Actions in an Appropriate Order of Importance • resolving situations that need immediate attention before handling low priority tasks • issuing control instructions in a prioritized, structured, and timely manner	**1 2 3 4 5**
11. Preplanning Control Actions • scanning adjacent sectors to plan for future and conflicting traffic	**1 2 3 4 5**
12. Handling Control Tasks for Several Aircraft • shifting control tasks between several aircraft when necessary • communicating in timely fashion while sharing time with other actions	**1 2 3 4 5**
13. Overall Prioritizing Scale Rating	**1 2 3 4 5**

IV – PROVIDING CONTROL INFORMATION	
14. Providing Essential Air Traffic Control Information • providing mandatory services and advisories to pilots in a timely manner • exchanging essential information	**1 2 3 4 5**
15. Providing Additional Air Traffic Control Information • providing additional services when workload permits • exchanging additional information	**1 2 3 4 5**
16. Overall Providing Control Information Scale Rating	**1 2 3 4 5**

V – COMMUNICATING	
17. Using Proper Phraseology • using words and phrases specified in the 7110.65 • using phraseology that is appropriate for the situation • using minimum necessary verbiage	**1 2 3 4 5**
18. Communicating Clearly and Efficiently • speaking at the proper volume and rate for pilots to understand • speaking fluently while scanning/performing other tasks • ensuring clearance delivery is complete, correct, and timely • speaking with confident, authoritative tone of voice	**1 2 3 4 5**
19. Listening to Pilot Readbacks and Requests • correcting pilot readback errors • acknowledging pilot or other controller requests promptly	**1 2 3 4 5**
20. Overall Communicating Scale Rating	**1 2 3 4 5**

VI – BIRD THREAT INFORMATION HANDLING - BASELINE		
21. Understanding Current Bird Threat Position • updating mental position of birds by querying other aircraft • follows up on PIREPS with other potentially affected aircraft in an active fashion • understands the most current bird threat position	1 2 3 4 5	N/A
22. Communicating Bird Threat Information • passes along most up-to-date information to affected aircraft for 15 minutes or until birds are no longer a factor • provides timely bird threat information to affected aircraft • Uses approved phraseology	1 2 3 4 5	N/A
23. Overall Bird Threat Information Handling - Baseline	1 2 3 4 5	N/A

VII – BIRD THREAT INFORMATION HANDLING - WISC		
24. Understanding Current Bird Threat Position • uses WiSC tools to understand current bird threat position	1 2 3 4 5	N/A
25. Communicating Bird Threat Information • passes along most up-to-date information to affected aircraft • provides timely bird threat information to affected aircraft • communicates when birds are no longer a factor as indicated by WiSC • uses approved proper WiSC phraseology	1 2 3 4 5	N/A
26. WiSC Tool Usage • Uses WiSC tools effectively and efficiently	1 2 3 4 5	N/A
27. Overall Bird Threat Information Handling - WiSC	1 2 3 4 5	N/A

APPENDIX I—DETAILED INDIVIDUAL PARTICIPANT SCHEDULE

		Day 1		
		Particpant 1/4	Particpant 2/5	Particpant 3/6
800	820	Arrive	Arrive	Arrive
820	840	Intro Briefing	Intro Briefing	Intro Briefing
840	900			
900	920	ATC Briefing	ATC Briefing	ATC Briefing
920	940			
940	1000			
1000	1020	Break	Break	Break
1020	1040	Training Run 1	Training Run 1	Training Run 1
1040	1100			
1100	1120			
1120	1140	Lunch	Lunch	Lunch
1140	1200			
1200	1220			
1220	1240	Training Run 2	Training Run 2	Training Run 2
1240	1300			
1300	1320			
1320	1340	Break	Break	Break
1340	1400	Training Run 3	Training Run 3	Training Run 3
1400	1420			
1420	1440			
1440	1500	Break	Break	Break
1500	1520	Experiment 1	Pre-HITL Survey	Pre-HITL Survey
1520	1540			
1540	1600	PSQ		
1600	1620	Open	Open	Open
1620	1640			

<table>
<tr><th></th><th></th><th colspan="3">Day 2</th></tr>
<tr><th></th><th></th><th>Particpant 1/4</th><th>Particpant 2/5</th><th>Particpant 3/6</th></tr>
<tr><td>800</td><td>820</td><td>Arrive</td><td>Arrive</td><td>Arrive</td></tr>
<tr><td>820</td><td>840</td><td rowspan="3">Pre-HITL Survey</td><td rowspan="2">Experiment 2</td><td rowspan="3">Background Brief</td></tr>
<tr><td>840</td><td>900</td></tr>
<tr><td>900</td><td>920</td><td>PSQ</td></tr>
<tr><td>920</td><td>940</td><td>Break</td><td>Break</td><td rowspan="2">Experiment 3</td></tr>
<tr><td>940</td><td>1000</td><td rowspan="2">Open</td><td rowspan="3">MITRE ConOps A1</td></tr>
<tr><td>1000</td><td>1020</td><td>PSQ</td></tr>
<tr><td>1020</td><td>1040</td><td rowspan="2">Experiment 4</td><td>Break</td></tr>
<tr><td>1040</td><td>1100</td><td>Break</td><td rowspan="3">MITRE ConOps A1</td></tr>
<tr><td>1100</td><td>1120</td><td>PSQ</td><td>Open</td></tr>
<tr><td>1120</td><td>1140</td><td>Break</td><td rowspan="2">Experiment 5</td></tr>
<tr><td>1140</td><td>1200</td><td rowspan="2">Open</td><td>Break</td></tr>
<tr><td>1200</td><td>1220</td><td>PSQ</td><td>Open</td></tr>
<tr><td>1220</td><td>1240</td><td rowspan="4">Lunch</td><td rowspan="4">Lunch</td><td rowspan="4">Lunch</td></tr>
<tr><td>1240</td><td>1300</td></tr>
<tr><td>1300</td><td>1320</td></tr>
<tr><td>1320</td><td>1340</td></tr>
<tr><td>1340</td><td>1400</td><td rowspan="3">MITRE ConOps A1</td><td rowspan="3">Background Brief</td><td rowspan="2">Experiment 6</td></tr>
<tr><td>1400</td><td>1420</td></tr>
<tr><td>1420</td><td>1440</td><td>PSQ</td></tr>
<tr><td>1440</td><td>1500</td><td rowspan="2">Experiment 7</td><td rowspan="3">Open</td><td>Break</td></tr>
<tr><td>1500</td><td>1520</td><td rowspan="3">MITRE ConOps A2</td></tr>
<tr><td>1520</td><td>1540</td><td>PSQ</td></tr>
<tr><td>1540</td><td>1600</td><td>Break</td><td rowspan="2">Experiment 8</td></tr>
<tr><td>1600</td><td>1620</td><td rowspan="2">Open</td><td>Break</td></tr>
<tr><td>1620</td><td>1640</td><td>PSQ</td><td>Open</td></tr>
</table>

		Day 3		
		Particpant 1/4	Particpant 2/5	Particpant 3/6
800	820	Arrive	Arrive	Arrive
820	840	Background Brief	MITRE ConOps A2	Experiment 9
840	900			
900	920			PSQ
920	940	Experiment 10	Break	Break
940	1000		Open	Open
1000	1020	PSQ		
1020	1040	Break	Experiment 11	
1040	1100	MITRE ConOps A2		
1100	1120		PSQ	
1120	1140		Break	Experiment 12
1140	1200	Break	Open	
1200	1220	Open		PSQ
1220	1240	Lunch	Lunch	Lunch
1240	1300			
1300	1320			
1320	1340	Debrief/ Exit Materials	Debrief/ Exit Materials	Debrief/ Exit Materials
1340	1400			
1400	1420			
1420	1440			
1440	1500			
1500	1520			
1520	1540			
1540	1600			

APPENDIX J—JUSTIFICATION FOR STATISTICAL ANALYSIS

Usability researchers are often confronted with analysis issues related to small sample size. This is particularly true in research where participant selection requirements are constrained to a group of highly experienced and specialized system users. In these cases, practical tradeoffs must be made in the approaches used to analyzing the data. The research team considered the value of presenting only descriptive statistics for this $N = 5$ simulation study against the value that a more enhanced analytical approach may yield. The justification for our approach is organized by two major decision points.

Question 1: Is there benefit gained by using inferential statistical methods in a preliminary study with such a small sample size?

The research team believes the answer to this question is "yes" with some reservation. In most cases, the use of inferential statistics allowed us to more clearly understand, and subsequently demonstrate, the relationships between data items. For example, participants may show complete agreement on qualitative measurements of system preference, but subsequent inferential analyses may suggest that the agreement might not be as powerful as the qualitative data suggests. On the other hand, there are instances where response variance is overly impacted by one participant's extreme response. Extreme responses in small research designs can greatly hinder the ability to find statistically significant differences and complicate the interpretation of the data. As such, the research team emphasizes that the results presented in this research are preliminary and more work is needed to validate these findings with a larger sample of participants.

Question 2: What test statistic is appropriate for the data set being analyzed?

In this simulation study the research team used the Friedman Analysis of Variance (ANOVA) by ranks to analyze the effect of the experimental condition on various measures. The Friedman ANOVA by ranks is the nonparametric equivalent to a Repeated-Measures ANOVA. The research team performed follow-up pairwise comparisons using the Wilcoxon signed-rank test if a statistically significant difference was found. The Wilcoxon signed-rank test is the nonparametric equivalent of a paired-samples *t* test.

The research team chose nonparametric tests because they are the most widely accepted inferential analysis method for analyzing ordinal questionnaire data. In addition, nonparametric tests are most appropriate when dealing with small sample sizes ($N < 20$) because they do not require the same underlying assumptions of normality, or equal variance, as the parametric equivalents do. Last, nonparametric methods are considered more conservative because they typically require greater evidence to find significance when compared to parametric tests [J-1].

REFERENCES

J-1. Warner, R., *Applied Statistics: From Bivariate Through Multivariate Techniques,* Los Angeles, Sage Publishing, 2013.