technical note technical note tech

RQ-7B Shadow UAS Operational Assessment: Marine Corps Air Station, Cherry Point, NC

Karen Buondonno, FAA, Navigation Team
Jeff Dressel, Ph.D., General Dynamics Information Technology

February 2011

DOT/FAA/TC-TN11/3

U.S. Department of Transportation
Federal Aviation Administration

William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/TC-TN11/3		

4. Title and Subtitle	5. Report Date
RQ-7B Shadow UAS Operational Assessment: Marine Corps Air Station, Cherry Point, NC	February 2011
	6. Performing Organization Code AJP-65
7. Authors Karen Buondonno, FAA, Navigation Team Jeff Dressel, Ph.D., General Dynamics Information Technology	8. Performing Organization Report No.
9. Performing Organization Name and Address AJP-65 - Engineering Development Services Federal Aviation Administration William J. Hughes Technical Center Atlantic City International Airport, NJ 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Aviation Administration Air Traffic Organization Mission Support Services AJV-13, Unmanned Aircraft Systems Group 490 L'Enfant Plaza Suite 3200 Washington, DC 20024	13. Type of Report and Period Covered Technical Note September 2009 - December 2009
	14. Sponsoring Agency Code

15. Supplementary Notes
None

16. Abstract
Under the alliance of Cooperative Research and Development Agreements, a group of Federal Aviation Administration (FAA) and Industry Partners have joined resources to investigate integration issues associated with Unmanned Aircraft Systems (UAS) operating in the National Airspace System (NAS). The FAA and their partners have planned a series of research and development activities, using multiple platforms and methods, to provide data to support the integration of UAS into the NAS. The human-in-the-loop, real-time simulation study described in this report was one such activity. Specifically, we explored the flight of the RQ-7B Shadow through a NAS transit operational volume while it transitioned to restricted airspace used for military flight training. The operation includes the use of a proposed Ground Based Sense and Avoid concept and technology. This research provides an opportunity for early visualization of the concepts involved and a snapshot of information concerning the impact of the proposed operation on the NAS.

17. Key Words	18. Distribution Statement
UAS, Unmanned Aircraft System, Ground Based Sense and Avoid, MCAS Cherry Point, RQ-7B, RQ-7B Shadow, Shadow 200, Marine Corps Air Station, US Marine Corps, Human-in-the-loop simulation	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
		80	

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Acknowledgements

We thank AAI Corporation for their support in this research. Rose Mooney and Rich Fagan are invaluable partners who support the project planning, design, and execution of this joint effort. John LaCosta and Chris Good provided technical support for the RQ-7B Shadow Unmanned Aircraft System (UAS) simulator. Josh Hendrix served as a UAS Pilot during shakedown and provided feedback on simulator performance.

We thank the research collaborators involved in this project, with whom the necessary concepts and issues of study were developed and refined. We express deep gratitude to Major Michael Hague and Lieutenant Colonel George Beach, US Marine Corps; Viva Austin, US Army; Thomas Spriesterbach, Johns Hopkins University – Applied Physics Laboratory; Kevin Warren, ASEC, Inc. and US Navy; and the US Marine Corps air traffic controllers and UAS Pilots who supported this joint government industry effort.

We thank our Federal Aviation Administration (FAA) partners, the FAA Unmanned Aircraft Systems Group, especially Ardyth Williams, who sponsors and supports this effort. We thank the FAA Unmanned Aircraft Program Office, especially Kerin Olson and James Sizemore, who provided project support, guidance, and share their UAS expertise.

We extend thanks to FAA Engineering Development Services, especially our FAA Manager, Paula Nouragas, who supplies unwavering support and guidance to the team. We thank Debbie Friel, FAA, and Katy White, FAA, for handling all of our complex and time-critical administrative issues and needs. Philip Maloney, FAA, and Jean-Christophe Geffard, GDIT, worked to maintain operation of the RQ-7B Shadow simulator and extract and process data for analyses. Steve Entis and Linda Costello, CSSI, Inc., analyzed historical air traffic data, designed and refined scenarios used in the study, and served as key air traffic control (ATC) subject matter experts (SMEs) throughout the simulation activities. Joe Romino, GDIT, provided invaluable feedback during simulation development, and served as both an ATC and pilot SME. Michael Levine, GDIT, provides technical editing expertise for all of our documentation, facilitates the live camera feed displays in the Central Viewing Area (CVA), and coordinates our many guests and observers.

We thank many individuals from the Laboratory Services teams at the FAA's William J. Hughes Technical Center. Robin Peterson-Brown, FAA, obtained and coordinated all laboratory resources and requirements for this project. Nick Marzelli, FAA, and Daniel Fumosa, GDIT, were instrumental in programming the new concepts simulated in the study, developing scenarios, and extracting and processing system data for analysis. Nick Roselli, FAA, provided communications expertise and helped implement live video feeds to the CVA. Haijun Wu, GDIT, implemented the controller display maps used in this study to emulate the customer's display environment. Joe Haubrich, FAA, supported and implemented the communications systems used in the simulation. Ed Horvath, GDIT, served as the test director for all laboratory operations during the study. Cindy Salas, GDIT, coordinated and supervised simulation pilot activities. Lee Starks, GDIT, coordinated and executed all of our audio/video recordings. Ed

DiProspero, FAA, expertly handled our technical requirements in an expeditious manner in the CVA, while Bill Dawson, FAA, offered other supplemental technical support in the space.

We also thank the FAA Concept Development and Validation Group for providing us excellent support with Tim Holth and Jerry Fink, CSSI, Inc., who served as ATC SMEs during shakedown and simulation.

Executive Summary

The Unmanned Aircraft Systems (UAS) Federal Aviation Administration (FAA) and Industry Team (known as UFIT) is engaged in a series of research and development activities, using multiple platforms and methods, to provide data to support the safe integration of UAS into the National Airspace System (NAS). One such activity is the research described in this report.

This Human-in-the-Loop (HITL) simulation, which was conducted December 1-3, 2009, at the FAA's William J. Hughes Technical Center, examined a subset of a proposed concept of employment for future operations as described in the Cherry Point Concept of Employment at Marine Corps Air Station Cherry Point (United States Navy, 2008). Specifically, we explored the flight of the RQ-7B Shadow through a NAS transit operational volume while it transitioned to restricted airspace used for flight training. The exercise provides an opportunity for early visualization of the concepts involved and a snapshot of information concerning the impact of the proposed operation on the NAS with human operators (i.e., air traffic controllers, a Ground Based Sense and Avoid [GBSAA] Observer, and pilots) included.

Specifically, this simulation activity:

- Models a proposed operational procedure for the transit of a UAS between Cherry Point Class D and a specific restricted area that includes a proposed GBSAA concept. The GBSAA concept includes a display that alerts the GBSAA Observer (GO) to the presence of potential threats using a visual alerting system.
- Focuses on a GBSAA concept that includes "yellow light" warning situations and the decision-making process such a situation evokes.
- Explores different pathways of communication by using two experimental conditions, each with unique procedures: configuration A, in which the GO position was paired with a controller, and configuration B, in which the GO position was paired with a UAS Pilot.
- Evaluates the effect of different winds aloft on the proposed operation.

A UAS Pilot participant and two air traffic control participants were recruited for this study. One critical assumption of this research is that while we provide data for a feasibility assessment of the proposed GBSAA concept, we did not simulate the actual algorithm that will be employed at Marine Corps Air Station Cherry Point. That is, we replicated the concept by using fixed radii for the "yellow light" and "red light" warning airspace, whereas the actual proposed concept will use a more sophisticated algorithm. Furthermore, the results discussed in this study are based on the minimum possible number of participants, and a limited number of observations. Thus, there was low statistical power for inference, and results can not be generalized to the population of interest, nor considered conclusive.

As studied, major observations included no loss of separation between any aircraft, workload was not a substantial issue, and the RQ-7B Shadow made a successful transition in 16 of 17 runs (with one successful "non-transition"). There were large configuration effects on the timeline to communicate the GO

decision to transit the UAS. Configuration B took nearly five times as long (i.e., nearly a minute) to communicate the decision to transit the RQ-7B Shadow to all three participants, relative to configuration A. With further refinement of the procedures and algorithm involved, this general concept appears to merit additional evaluations. Therefore, it is recommended that comprehensive safety and validation studies be conducted when a final operational concept has been developed.

1. Introduction

Within the aviation community, interest in using Unmanned Aircraft Systems (UAS) for a broad range of purposes is rapidly increasing, making UAS access to the National Airspace System (NAS) a priority. Today, there are interim policies, guidance materials, and operational procedures that allow for limited access to the NAS, but these exception processes for approval are time-consuming and constrain user operations. The central challenge for both UAS users and service providers is the lack of validated operational procedures, certifications, standards, and policies for ***routine*** UAS access to the NAS.

Under the alliance of Cooperative Research and Development Agreements (CRDA), a group of Federal Aviation Administration (FAA) and Industry Partners has joined resources to investigate UAS-NAS integration issues. The resulting team, known as the UAS FAA and Industry Team (UFIT)[1], is guided by the common goal to advance UAS operations beyond the exception processes of the Certificate of Waiver or Authorization (COA) and Special Airworthiness Certificates Experimental Category to achieve broader and routine NAS access outside of special use airspace. This includes examining concepts and technologies that will potentially lead to integration of UAS into the Next Generation Air Transportation System (NextGen). The key to achieving this goal is a safety case that ensures the continued integrity of the NAS. In order to produce the evidence required to address both near-term and far-reaching challenges of true integration, extensive research is needed. To provide the data toward required to fulfill this goal, the UFIT has planned a series of research and development activities using multiple platforms and methods. The research described in this report is one such activity.

1.1 Background

The RQ-7B Shadow is a short-range reconnaissance UAS. The United States Marine Corps (USMC) Marine Unmanned Aerial Vehicle Squadron Two has a near-term need to train and qualify RQ-7B Shadow operators prior to deployment to theaters of operation around the world. This UAS training has been conducted in accordance with an FAA COA between the Department of Defense (DoD) and the FAA, taking place at the Marine Corps Air Station (MCAS) in Cherry Point, North Carolina.

The ability to “see and avoid” and remain “well clear” of other aircraft is part of the regulations governing the general operations of aircraft in the NAS under Title 14 Code of Federal Regulations (14CFR), Part 91, §91.111 and §91.113. Without a pilot onboard, UAS are lacking the critical function and cannot directly comply with these operational regulations. Sense and Avoid (SAA) is the capability of an Unmanned Aircraft (UA) to remain “well clear” from and avoid collisions with other airborne traffic and is the combination of UAS Self-Separation plus Collision Avoidance protection as a means of compliance with see and avoid regulations. UAS systems will have to demonstrate the capability of SAA to

[1] UFIT partners currently include: FAA Aviation Safety Organization, Flight Standards Service; FAA Air Traffic Organization, Mission Support Services and NextGen and Operations Planning; AAI Corporation; General Atomics Aeronautical Systems Inc.; and GE Aviation Systems LLC.

perform the function of "see and avoid" to an acceptable level of safety in order to gain routine access into the NAS.

Accordingly, the USMC is seeking relief from the current requirement for ground observers in order to support a complex and changing training environment while maintaining an acceptable safety level for operating in the NAS. Specifically, this study explores a concept using Ground Based Sense and Avoid (GBSAA) operations, including radar.

Figure 1 characterizes the operations and communications currently in place for UAS operations at MCAS Cherry Point, notably the inclusion of ground observers.

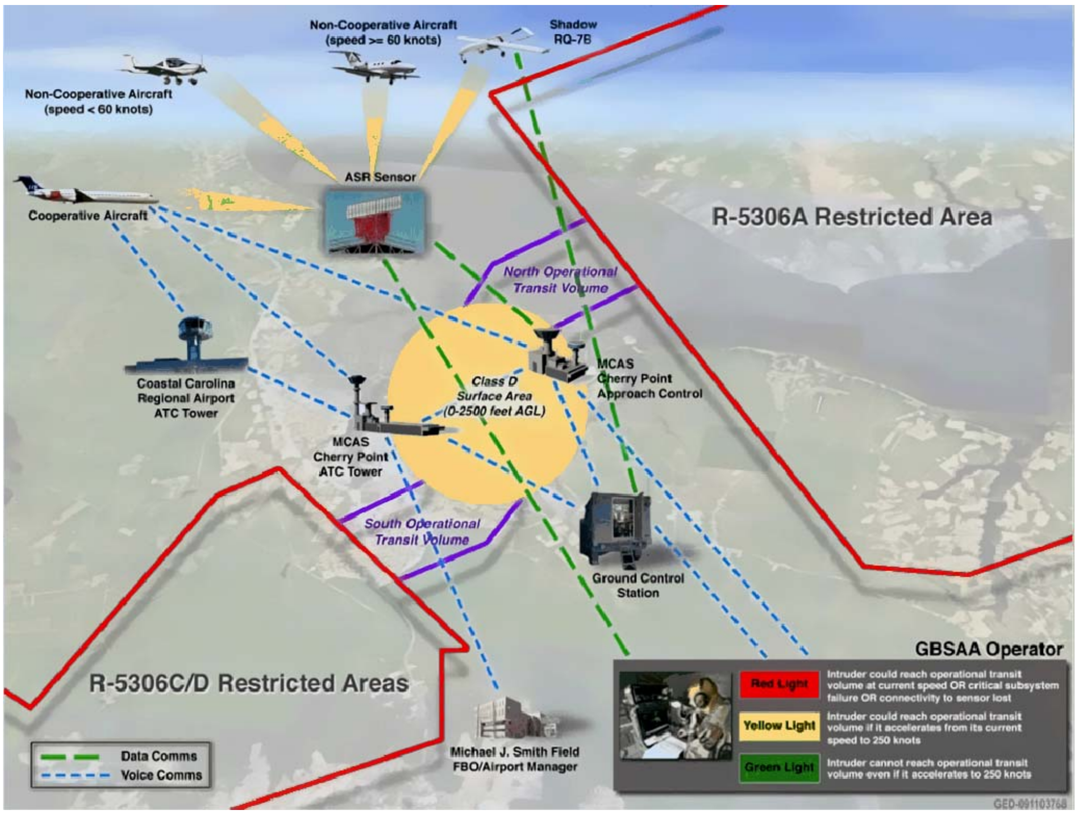

Figure 1. Current Operations and Communication Paths

Conducted on December 1-3, 2009, at the FAA William J. Hughes Technical Center (WJHTC), the study examines a subset of a proposed concept of employment (ConEmp) for future operations as described in the Cherry Point Concept of Employment at Marine Corps Air Station Cherry Point (United States Navy, 2008). Specifically, we explored the flight of the RQ-7B Shadow through a NAS transit operational volume while it transitioned to restricted airspace used for flight training. It presents a method of UAS operations using surveillance radar and appropriate procedures to establish a flexible "zero conflict airspace"[2] surrounding the south transit operational volume between MCAS Cherry Point Class D Airspace and Restricted Area R5306C. The MCAS Class D Airspace is a

[2] For a full description of zero conflict airspace, refer to the Cherry Point Concept of Employment at MCAS Cherry Point (US Navy, 2008).

joint use airport (i.e., military and civilian operations). The information exchanges, communications, and interactions among USMC UAS Pilots, the RQ-7B Shadow, the air traffic controllers, and air traffic control (ATC) system were investigated. Note that the full ConEmp includes two NAS transit operational volumes and operations to and from two restricted areas (R5306A and R5306C/D).

1.2 Objective

The primary goal of this human-in-the-loop (HITL) simulation exercise was to explore a proposed operational concept, support refinement of the concept, and collect data which may support future evaluations. This research endeavor was purposely designed to be a limited scope HITL simulation exercise. As such, it does not provide data with statistical rigor (i.e., there is limited power for the use of statistical data analysis), nor does it validate the proposed operations or technology explored. The exercise provides an opportunity for early visualization of the concepts involved and a snapshot of information concerning the impact of the proposed operation on the NAS with human operators (i.e., controllers, GBSAA Observers [GO], and pilots) included.

Specifically, this simulation activity:

- Models a proposed operational procedure for the transit of a UAS between Cherry Point Class D Airspace and a specific restricted area that includes a proposed GBSAA concept. The GBSAA concept includes a display that alerts the GO to the presence of potential threats using a visual alerting system.
- Focuses on a GBSAA concept that includes “yellow light” warning situations and the decision-making process such a situation evokes.
- Explores different pathways of communication by using two experimental conditions, each with unique procedures: configuration A, in which the GO position was paired with a controller, and configuration B, in which the GO position was paired with a UAS Pilot.
- Evaluates the effect of different winds aloft on the proposed operation.

1.3 Research Partner Roles and Responsibilities

1.3.1 United States Marine Corps

The USMC provided UAS Pilots, air traffic controllers, and subject matter expert (SME) consultation for the study. The USMC also provided support materials and information for simulation development such as airspace data, flight plan information, and procedural data.

1.3.2 Federal Aviation Administration

As a member of UFIT, the FAA designed and conducted the simulation and analyzed the resulting data. The FAA provided a Principal Investigator (PI), research team, and all technical staff to support the study.

1.3.3 Textron/AAI Corporation

Textron/AAI Corporation has a formalized CRDA[3] with the FAA to support several activities set forth in the Unmanned Aircraft System Integration Evaluation Plan (draft, Federal Aviation Administration, 2010). As a member of

[3] The CRDA between AAI Corporation and the FAA (09-CRDA-0259) is valid beginning 6/29/09.

UFIT, for this exercise AAI Corporation provided an RQ-7B Shadow simulator system, technical expertise for this system, UAS Pilot SME support, and additional data processing assistance.

2. Method

2.1 Participants

This exploratory, limited scope study includes a single sample of three representatives from the target population.

2.1.1 Air Traffic Controllers

One full performance level air traffic controller from the USMC staffed the required Cherry Point Approach Control position for the simulation. The participant controller controlled simulated air traffic in the virtual environment. The controller interacted with the UAS Pilot participants as well as simulation support staff functioning as simulation pilots and ghost controllers (see Section 2.3). This controller participant also served the role of GO on predetermined experimental runs (changing positions with the GO participant).

2.1.2 Ground-Based Sense and Avoid Observer

One full performance level air traffic controller from the USMC served as the GO in the study. This new GO position is integral to the proposed operations. The procedures for this position are described in section 2.6.2. The GO received the same radar information as the air traffic controller, as well as additional primary radar information that is typically filtered from the ATC radar scope. Using the radar information and a new GBSAA alerting system, the GO made a decision concerning the UAS transit through the defined corridor between Class D Airspace and restricted airspace. This decision was communicated in half the trials to the ATC position (who then communicated the decision to the UAS Pilot), and in half the trials to the UAS Pilot directly (who then communicated the intent to transit to ATC). This controller participant also served the role of Approach Controller on predetermined experimental runs (changing positions with the Approach controller).

2.1.3 UAS Pilot

One trained and qualified RQ-7B Shadow Pilot (referred to by the USMC as an Air Vehicle Operator, or AVO) from the USMC flew the UAS simulator during the study. This study did not employ other crewmembers sometimes utilized in the field (e.g., positions referred to by the USMC as a Mission Payload Operator or Mission Commander).

The UAS Pilot interacted with ATC and GO participants as well as simulation support staff functioning as simulation pilots and simulation controllers (see Section 2.3).

2.2 Research Personnel

Researchers from the FAA and contract support personnel designed and implemented the research effort. A PI supported by research and laboratory support services staff conducted the exercise. The PI was responsible for the overall administration of the exercise, including briefings, experimental procedure, and data collection. Supporting research staff prepared experimental materials and assisted in the collection, analysis, and reporting of data.

2.3 Simulation Support Staff

Simulation pilots and controllers provided assistance to complete the simulated environment in which the exercise participants operated.

2.3.1 Simulation Pilots

Four simulation pilots supported the conduct of the exercise during shakedown and the experimental runs. All simulation pilots gained familiarity with the airspace, scenarios, activities, and procedures during scenario development and shakedown practice. Each simulation pilot controlled a number of individual aircraft by issuing commands on their own workstation, which consists of a computer, keyboard, monitor, and communication equipment. The simulation pilots issued commands in response to verbal instructions from air traffic controllers, much as an actual pilot controls an aircraft. These commands were pre-defined strings of alphanumeric characters entered through a standard workstation keyboard. Each simulation pilot also had a plan view (i.e., 2D) display of traffic and a list of assigned aircraft. For each assigned aircraft, the simulation pilots had information regarding the aircraft's current state and corresponding flight plan data.

2.3.2 Simulation Controller

To simulate the interaction of Cherry Point controllers with controllers performing automation entries and voice communications associated with adjacent airspace/positions (Approach Control North position, Tower position, and New River Radar position), one simulation controller (known as the "ghost controller") was used. This simulation controller participated during shakedown and experimental runs. The simulation controller gained familiarity with the airspace, scenarios, and procedures during scenario shakedown and was fully prepared for the experimental runs.

2.3.3 Subject Matter Expert Observers

Two ATC SMEs served as over-the-shoulder observers of the controller and GO. One manned aircraft pilot SME served as an over-the-shoulder observer of the UAS Pilot. The SME observers manually collected supplemental simulation data.

2.4 Assumptions and Limitations

One critical assumption of this research is that while we provided data for a feasibility assessment of the proposed GBSAA concept, we did not simulate the actual algorithm that will be employed at MCAS Cherry Point. That is, we replicated the concept by instead using fixed radii for the "yellow light" and "red light" warning airspace, whereas the actual proposed concept will use a more sophisticated algorithm. Other aspects of the concept were also not employed, such as an audio warning tone to accompany red-light warnings, and the ability of the GO to manually upgrade aircraft warning level color codes. Additionally, this simulation had the limitation of not employing crewmembers assisting the UAS Pilot. To this end, our data describe the use of the "red-yellow-green" warning light concept itself, and not the formulas used to calculate when and how these warning lights will be presented, nor the full crew potentially employed in these operations.

Furthermore, the results discussed in this study are based on the minimum possible number of participants, and a limited number of observations. Thus, there is low statistical power for inference, and results can not be generalized to the population of interest, nor considered conclusive.

2.5 Equipment

This exercise was conducted using the FAA WJHTC's NextGen Integration and Evaluation Capability (NIEC). The NIEC allows for a flexible simulation environment that can link and enable simulation-specific components, as needed. For this study, UAS and NAS platforms were integrated to emulate the RQ-7B Shadow flying in Cherry Point Approach Control airspace. Models, workstations, and equipment used are described below.

2.5.1 Unmanned Aircraft System Model

The RQ-7B Shadow six degrees of freedom (6 DoF[4]) simulator used for this exercise is a hardware-in-the-loop simulator (HILSIM). The pilot interface of the HILSIM runs on two Linux workstations, with software written by CDL Systems (an AAI Corporation-contracted company). Additionally, these workstations are supported by three Microsoft Windows workstations that simulate the aircraft and its aerodynamic performance profile. This software is written by AAI Corporation. The HILSIM ground station is comprised of the following:

- Two stations, one used by the UAS Pilot and one used by another crewmember operating the payload; each has one monitor, one joystick, one QWERTY keyboard, and one mouse (note: either or both sides can be configured as the UAS Pilot station).
- One station hosting the 6 DoF model.
- One station hosting the Ground Data Terminal simulator.
- One station hosting the Payload simulator (which was vacant in this simulation).
- One ACE-II (Avionics)
- One Communications Portal Station to facilitate communication between ATC, GO, or both.

The HILSIM development is a cooperative effort between AAI Corporation and the US Army. Dynetics, Inc., of Huntsville, Alabama, was contracted by the US Army to develop a high fidelity 6 DoF simulation of the block 1B airframe. The block 1B simulator has been tailored to interface with the Shadow Flight Management System/Flight Control System (FMS/FCS) avionics (the new avionics package of the RQ-7B Shadow system). Dynetics has since been responsible for the development and configuration control of the 6 DoF aero model and support software on the simulation PC (developed by the DoD Joint Modeling and Simulation System). AAI Corporation has been similarly

---

[4] Six degrees of freedom (6 DoF) refers to motion of a rigid body in three-dimensional space, namely the ability to move forward/backward, up/down, left/right (translation in three perpendicular axes) combined with rotation about three perpendicular axes (roll, yaw, pitch). As the movement along each of the three axes is independent of each other and independent of the rotation about any of these axes, the motion indeed has six degrees of freedom.

responsible for the avionics portion of the simulation code. The AAI Corporation portion of the HILSIM code has been developed and controlled using ISO 9000 standards and other approved software development procedures, including quality assurance reviews and peer level software reviews. For this exercise, a non-flight FMS/FCS was integrated as part of the HILSIM. A schematic of components of the UAS model is seen in Figure 2.

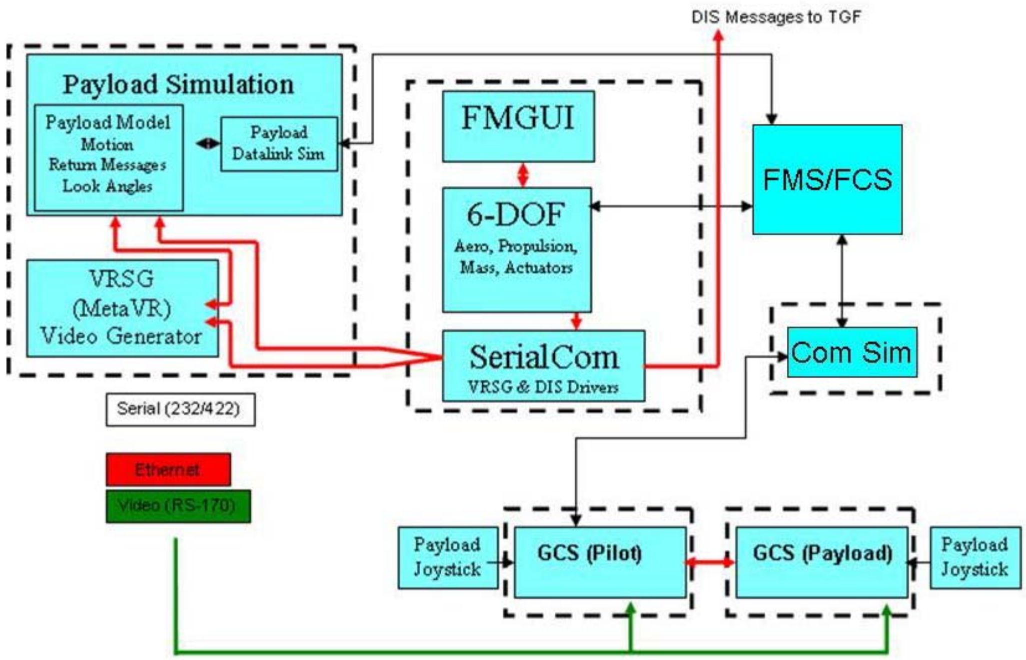

Figure 2. Components of RQ-7B Shadow Model

2.5.2 National Airspace System Model

We used the Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) ATC simulator and the Target Generation Facility (TGF) to present the air traffic on ATC workstations for this exercise. TGF allows researchers to capture and/or derive information about aircraft trajectories, aircraft proximity, performance characteristics and profiles, and other relevant data for use in subsequent analysis. The TGF version used for this study was TGF2009-11-13-T1332-notime.jar.

For this simulation, DESIREE emulated both en route and terminal controller functions as they exist today. DESIREE receives input from TGF that allows it to display information on the radar-scope, including radar tracks, data blocks, and sector maps. It also allows controllers to perform the typical functions that they would perform in an operational environment, for example, performing handoffs (i.e., aircraft radar identification transfers) and entering data into the Host computer. Like TGF, DESIREE has data collection capabilities and can record information on all controller entries made during a run. Software engineers at the WJHTC developed both DESIREE and TGF.

2.5.2.1 Simulation Pilot Workstations

There were three simulation pilot workstations in this experiment. These workstations each consist of a computer, keyboard, monitor, and communication equipment. The simulation pilots also had a plan view display of traffic and a dynamic list of assigned aircraft. The simulation pilots had information regarding the aircraft's current state and corresponding flight plan data for each assigned aircraft.

2.5.2.2 Air Traffic Control Workstation Consoles

An emulated Standard Terminal Automation Replacement System (STARS) workstation represented the Approach East sector (1E) at MCAS Cherry Point. The air-ground (A/G) frequency emulated for this position was VHF = 124.1. The STARS maps and toolbar format for this position were provided by the USMC. The radar range is 60 nautical miles (nm).

The data blocks were depicted as follows:

ACID [1]	HO_ [2]
Altitude [4]	Ground speed/# and type a/c, requested altitude [3]

1. ACID – aircraft ID. Either the call sign or the beacon code, depending on track status (not shared).
2. HO_ – all terminal positions are combined to 1E.
3. Shared display with ground speed, number and type of aircraft, requested altitude (i.e., R120, RVFR). Display alternates information every second. If a/c is on a filed flight plan with a local tag, it will display the requested altitude. Otherwise, that information does not display.
4. Altitude shown in hundreds of feet (i.e., 900 feet is shown as 009, 18,000 is shown as 180).

The STARS display shows Visual Flight Rules (VFR) aircraft squawking 1200 with altitude/ground speed only and is tagged as a "V". We used Runway 32 for arrivals and departures. The designator (aircraft ID) for the UA was NITEOWL in all scenarios. The discrete beacon code assigned to this aircraft was 0137.

A separate STARS workstation displaying all aircraft in the surrounding sectors was utilized by the ghost controller. The A/G frequency emulated for this position was VHF = 135.30. A ground-ground frequency was also in place so that the Approach Control position could realistically communicate with the ghost controller.

2.5.2.3 GBSAA Observer Workstation Console and Alerting Logic

An emulated STARS console containing additional primary radar target information (for the GO workstation) and a modified and simplified emulation of the proposed three-color display alerting system was used for this study[5]. Screen captures of the GO radar scope show the yellow-light and red-light traffic conditions as depicted in Figure 3 and Figure 4, respectively.

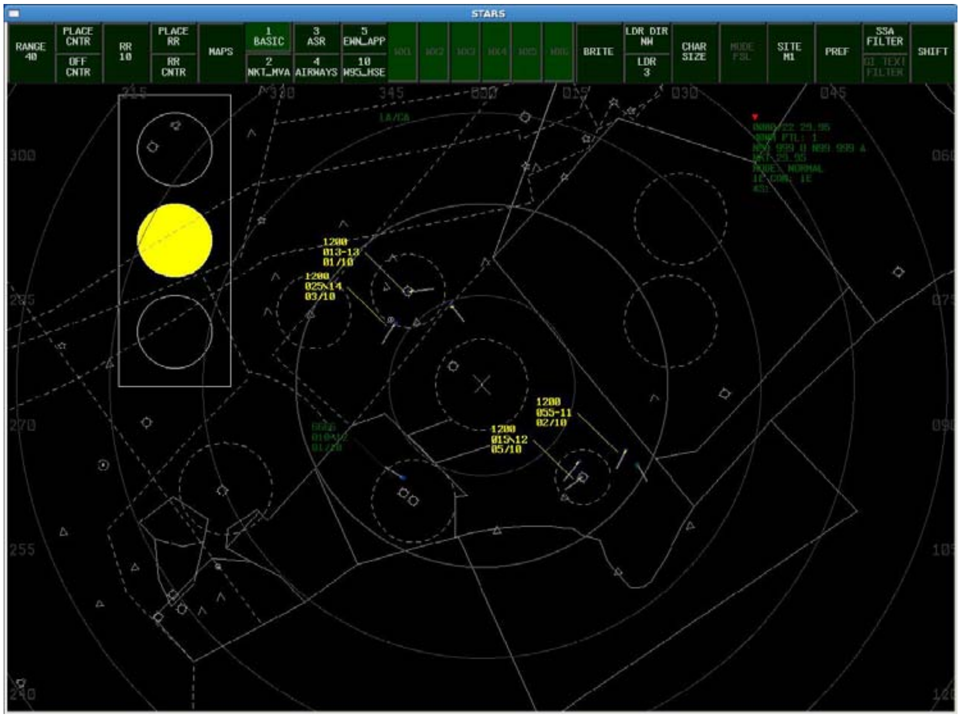

Figure 3. GO Scope Screen Capture in Yellow-Light Condition

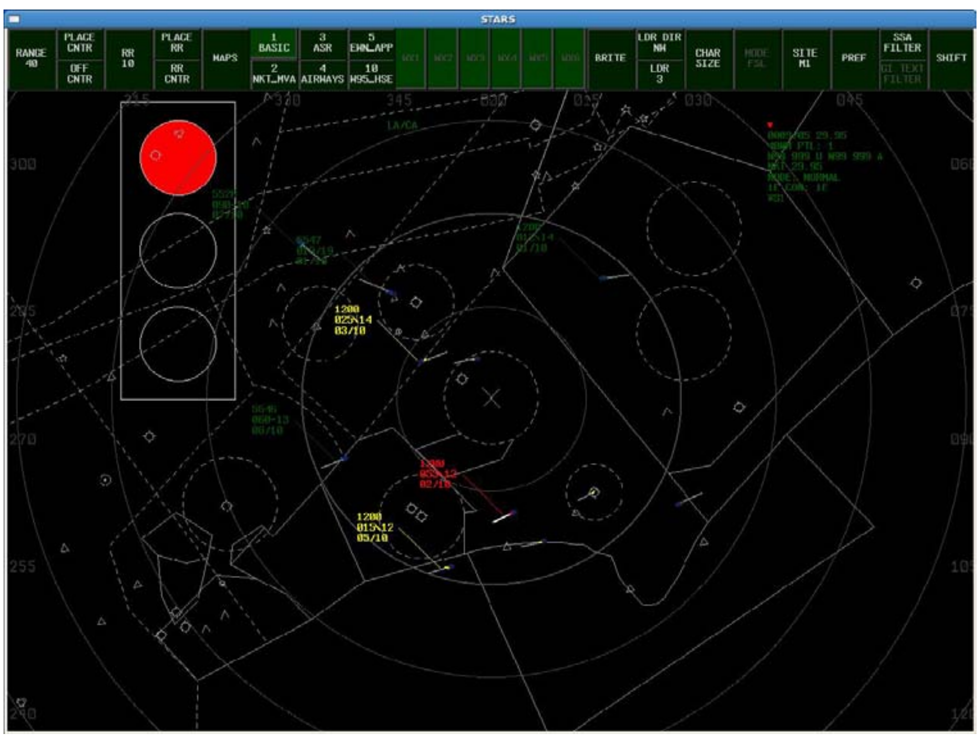

Figure 4. GO Scope Screen Capture in Red-Light Condition

[5] For a full description of the GBSAA concept, including the alerting logic, refer to the Cherry Point Concept of Employment at MCAS Cherry Point (US Navy, 2008).

The GO console displays the same tool bars and information as the ATC console. However, only limited data block information is presented. Additionally, there is a red-yellow-green display indicator located in the upper left corner of the GO console that does not occlude the toolbar. The three-color display indicator utilizes the following logic: two non-visible, concentric circles centered at latitude N 34^{o} 48’ and longitude W 76^{o} 56’, with a radius of 7.9 nm for the “red” warning area and a radius of 18.3 nm for the “yellow” warning area. These circles were themselves non-visible to emulate the proposed dynamic warning areas, which will not display fixed-radii circles. When an aircraft encroaches on these areas, the data block will change to the corresponding color of the warning area. If an aircraft is outside the two circles, its color is green. The red-yellow-green display reflects the location of aircraft within the circles, with red having priority. The GO area of coverage was the same as that which Approach Control has available (60 nm). For these simulations, we will assume the radar is located at the center of the Cherry Point Airfield (see detail in airspace description, section 2.6.1).

2.5.3 Communication System

A simulated communication system permitted selection, interconnection, and activation of communication pathways between the simulated aircraft and the air traffic controllers. The communication system was used for all air-to-ground and ground-to-ground communications including the GO position when applicable. The communication input keypads for ATC were configured to emulate the communication capabilities of the 1E sector and all surrounding sectors that were staffed by the ghost controller. All communications were recorded. The emulated communication system used for this study is a unique combination of laboratory designed and fielded systems. The UAS Pilot used the Interim Voice Switch Replacement (IVSR), the air traffic controller and GO used the Rapid Deployment Voice Switch, and the simulation pilots used the Combined Control and Communication System.

2.5.4 Workload Assessment Keypad

Workload Assessment Keypads (WAK) were present at each participant position (i.e., ATC, GO, and UAS Pilot), who all received complete WAK instructions at the beginning of the experiment. The WAK allows for the electronic capture of subjective workload at regular intervals from the study participants. The WAK consists of a touch panel display with seven numbered buttons. The WAK prompts the participant, with auditory and visuals prompts, to press a button to provide their subjective workload ratings. In this simulation, we set the WAK to prompt the participants for a rating every two minutes. During the prompt, the numbered buttons on each device illuminated and emitted a brief tone. When prompted, participants indicated their current level of workload by pressing one of the numbered buttons, with “1” indicating low workload and “7” indicating high workload. The buttons remained illuminated for the duration of the response period (20 seconds) or until a participant made a response, whichever occurred first. If no response was made within the 20-second period, a score of 99 was recorded, indicating that a participant was too busy to respond (see the results section for a discussion of an anomaly in the WAK data).

2.5.5 Audio-Video Data Recorders

Each run was video and audio recorded at the ATC, GO, and UAS Pilot positions to capture the activities of the operation and the interaction between participants.

The purpose of these recordings was to supplement other subjective and objective data being obtained. Audio recordings captured the conversations between the ATC, GO, UAS Pilot, and all simulation frequencies. Video recordings captured general views of each participant's actions. For each run, the video and audio was time stamped and recorded to digital files. In addition, live video and audio was streamed to the Central Viewing Area within the WJHTC for observers and visitors. All observers and visitors to the study documented their attendance in a visitor's log.

2.6 Materials

2.6.1 Airspace

2.6.1.1 Cherry Point Airspace

This simulation emulated MCAS Cherry Point's airspace, which is the largest MCAS and home to the 2nd Marine Aircraft Wing. Cherry Point's Approach Control Airspace (A-530) is surrounded by Seymour Johnson Approach to the northwest; Washington Center to the north, west, and east; FACSFAC VACAPES to the east and southeast; and Wilmington Approach to the west. Cherry Point owns airspace from the surface up to and including flight level (FL) 180.

The following Class D Airspace are contained within Cherry Point's airspace and are reserved for exclusive DoD use: MCAS Cherry Point Airport (NKT), MCAS New River (NCA), and Marine Corps Auxiliary Landing Field (MCALF) Bogue Field (NJM). Coastal County Regional Airport (EWN), formerly known as Craven County Regional Airport, is another Class D Airspace contained within Cherry Point's airspace that is available for public use.

Cherry Point Approach is responsible for the arrival, departure, and en route flights of the following airfields: NKT, NJM, and Michael J. Smith Airport (MRH). NCA and EWN, simulated in this environment, have an approach control facility and VFR tower operation, respectively. NKT provides sequencing of those arrivals and departures.

2.6.1.2 Restricted Areas

There are three adjacent restricted areas to A-530: R5306A to the northeast and R5306C, R5306D, and R5306E to the southwest. R5306A is continuously in effect to but not including FL 180. R5306D is continuously in effect to but not including FL 180. R5306C is continuously in effect from 1200 feet above ground level (AGL) to but not including FL 180. R5306E is continuously in effect to but not including FL 180, but is not currently utilized for RQ-7B Shadow operations. The controlling agency for R5306A-E is Cherry Point Approach Control. Figure 5 shows the applicable area of the Charlotte sectional chart for MCAS Cherry Point and vicinity, including the restricted areas of interest.

Figure 5. Charlotte Sectional Chart for MCAS Cherry Point and Vicinity

2.6.1.3 Transit Operational Volumes

For this study, we emulated Sector 1E in the typical configuration where all sectors adjacent to 1E are combined with 1E. Operations focused on UAS transit from Class D Airspace through the south transit operational volume to R5306C. The north and south UAS transit operational volumes (depicted as red outlined areas in Figure 6) are not within the NKT Class D Airspace. The transit volumes have been established from known aircraft use in the Cherry Point area and a long history of UAS operations. The route of the RQ-7B Shadow through the south transit volume is nominally down the middle of the defined area. This route yields a distance of approximately 6.5 nm through which the UAS has to fly between the Class D Airspace and the restricted area. It is important to note that this study only simulated the south transit UAS operations.

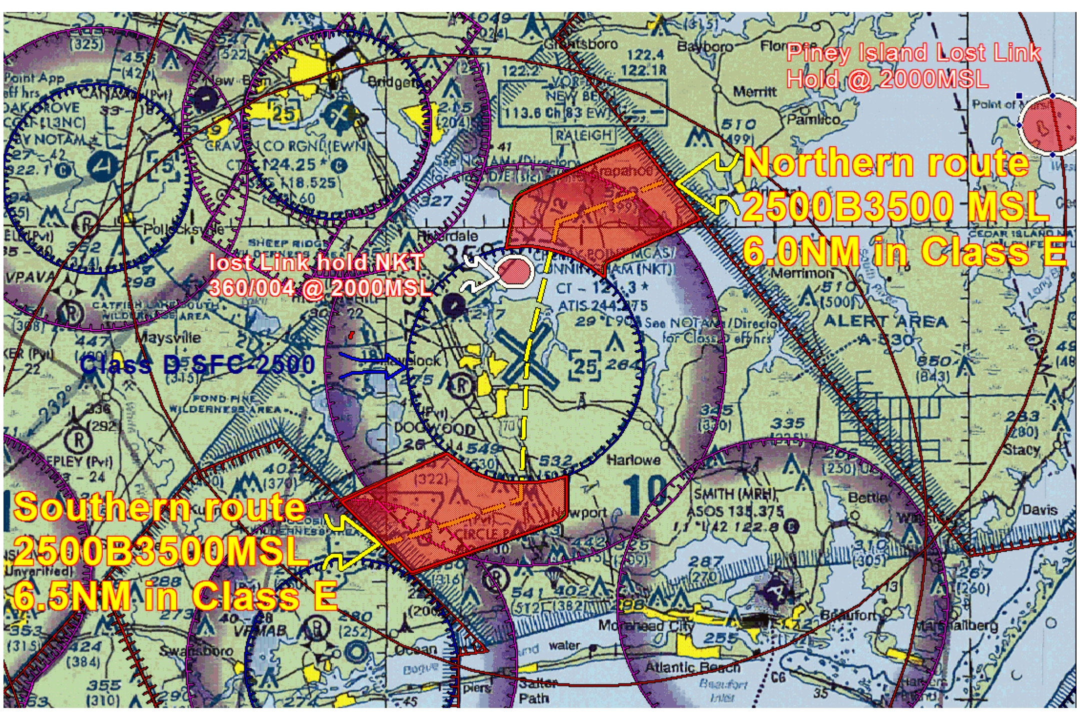

Figure 6. Transit Operational Volumes

2.6.2 Operational Procedures

The operations in this simulation are dependent on tasks that are related to the use of reasoning and perception. These tasks are interactive and dynamic. In particular, these operations involve coordination of cognitive and human performance systems, team processes, situational awareness, planning, and communication.

For the purposes of this exploratory study, a preliminary set of procedures for the proposed concept was developed. The operational procedures are limited to a specific subset of the proposed concept and airspace being examined. Different pathways of communication were explored by using two experimental configurations (described in section 2.7.1), each with unique operational procedures. It is not within the scope of this study to resolve the issue of whether the GO or ATC position has responsibility for SAA tasks, but rather to present different configurations to help inform such a decision.

An RQ-7B Shadow began each experimental run holding at 1500 feet AGL above MCAS Cherry Point. It then flew to latitude N 34^{o} 50' and longitude W 76^{o} 53', climbing to 2500 feet, which is a point within the Class D Airspace and clear of any populated areas. The RQ-7B Shadow held, advised ATC (or GO, depending on which configuration was being run) of the hold status, and awaited further instructions.

When the UAS was positioned in a holding pattern at the entrance to the south transit area, the UAS Pilot requested passage through the operational transit volume. The UAS was instructed not to move through the transit area to the restricted area until such time as all cooperative and non-cooperative traffic in the threat area were accounted for within the parameters set forth in the operational guidance. Potential air hazards were evaluated using the GO position.

The air hazards (as defined in the Cherry Point ConEmp and for the purposes of this study) are defined as follows:

- Cooperative aircraft: aircraft squawking a Mode C beacon code in contact with ATC.
- Non-participating aircraft: aircraft squawking a Mode C beacon code (1200) and not in contact with ATC (VFR).
- Non-cooperative (tracked) aircraft: aircraft with a tracked primary radar return, but not reinforced with a beacon code. No Mode C or other altitude information and no radio contact with ATC.
- Non-cooperative (untracked) aircraft: aircraft with a primary radar return only. No Mode C or other altitude information associated with return. No radio contact with ATC.

Procedures for Configuration A (GO paired with ATC):

- GO is physically co-located and in direct communication with NKT ATC (see Figure 7)

- GO maintains awareness of threats in the area
- GO provides ATC a transit decision for the UAS
- GO will have the discretion to override yellow threats and consider them to be green if all the following conditions are met:
  - The yellow threat is in a special area in the vicinity of EWN and MRH airports, as described in the ConEmp (US Navy, 2008).
  - The GO interprets a pattern of intent suggesting the yellow threat will remain in the special area.
  - The GO determines the yellow threat is oriented away from the transit volume.
- UAS Pilot reports to ATC that UAS is established in holding and intent is to transit to restricted area. ATC acknowledges this intention and advises "continue holding"
- When transition decision is received from the GO, ATC will review the conditions for transit based on radar display and information presented. When/if ATC is satisfied with the conditions, they will issue transition approval to the UAS Pilot
- Upon receiving transit approval, the UAS Pilot will climb the UAS to 3000 feet and maintain a ground speed of at least 90 knots and transit the airspace into the restricted area
- GO and ATC monitoring continues through transit

<u>Procedures in Configuration B (GO paired with UAS Pilot)</u>:

- GO is in direct communication with the UAS Pilot. Physical location is remote from ATC and UAS Pilot (see Figure 8)
- GO maintains operational awareness of threats in the area
- GO provides UAS Pilot a transit decision for the UAS, or may estimate when clear
- GO will have the discretion to override yellow threats and consider them to be green if all the following conditions are met:
  - The yellow threat is in a special area in the vicinity of EWN and MRH airports, as described in the ConEmp (US Navy, 2008).
  - The GO interprets a pattern of intent suggesting the yellow threat will remain in the special area.
  - The GO determines the yellow threat is oriented away from the transit volume.
- UAS Pilot reports to ATC and GO that UAS is established in holding and is preparing to transit to restricted area. ATC acknowledges this intention and advises "continue holding"
- ATC communicates to UAS Pilot any positive or negative traffic conditions for transit
- UAS Pilot is in communication with GO
- When UAS Pilot receives transition approval from GO, UAS Pilot will inform ATC that UAS is in transit.
- ATC will review conditions and acknowledge transit or report conflicts to the UAS Pilot prior to UAS exiting Class D Airspace
- UAS Pilot begins transit to restricted area
- Climbs to 3000 feet

- Maintains ground speed of 90 knots or greater for duration of transition
- GO and ATC monitoring continues through transit

On the third day of simulation, the above procedures were modified. Participants were briefed and trained on the changes. The experimental runs involved were runs 14, 16, and 9A (scenarios S2W25A, S3W25A, and S4W0A; see Table 1). Due to simulation equipment failure, these runs were only operated under Configuration A.

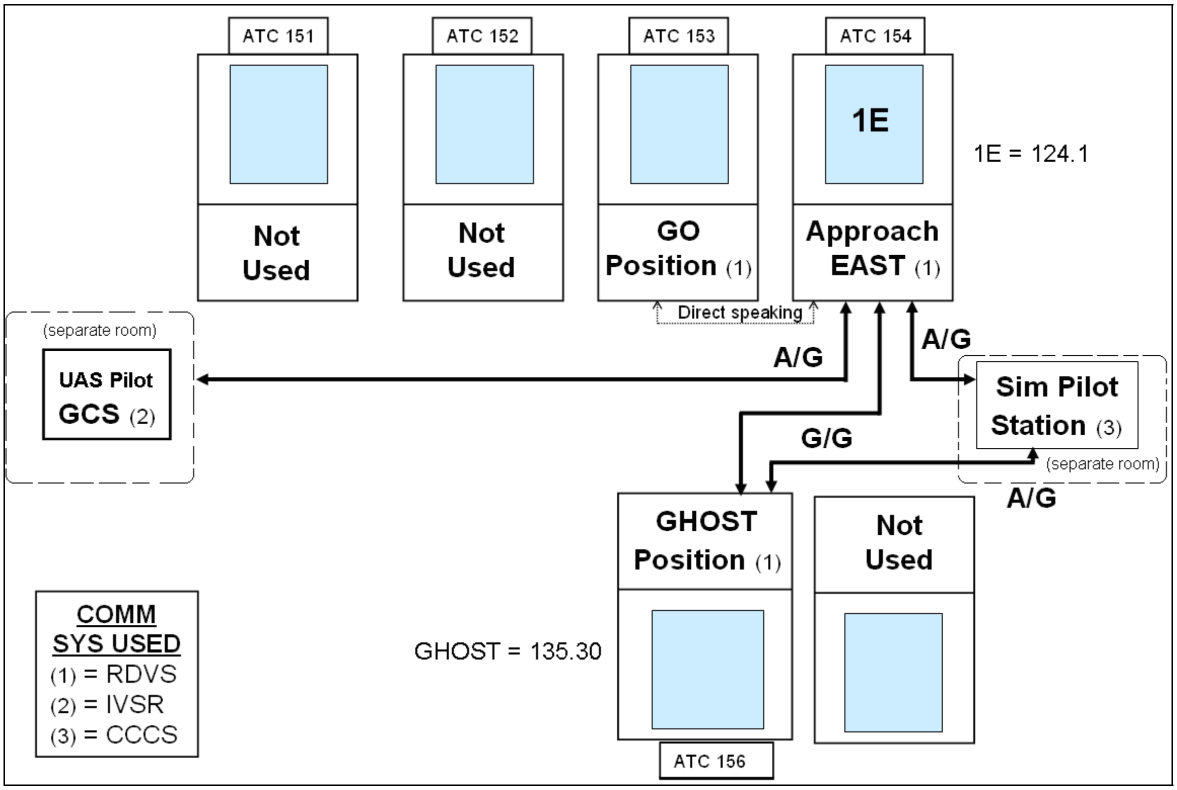

Figure 7. Lab Configuration A
Note: A/G = Air-to-Ground, G/G = Ground-to-Ground

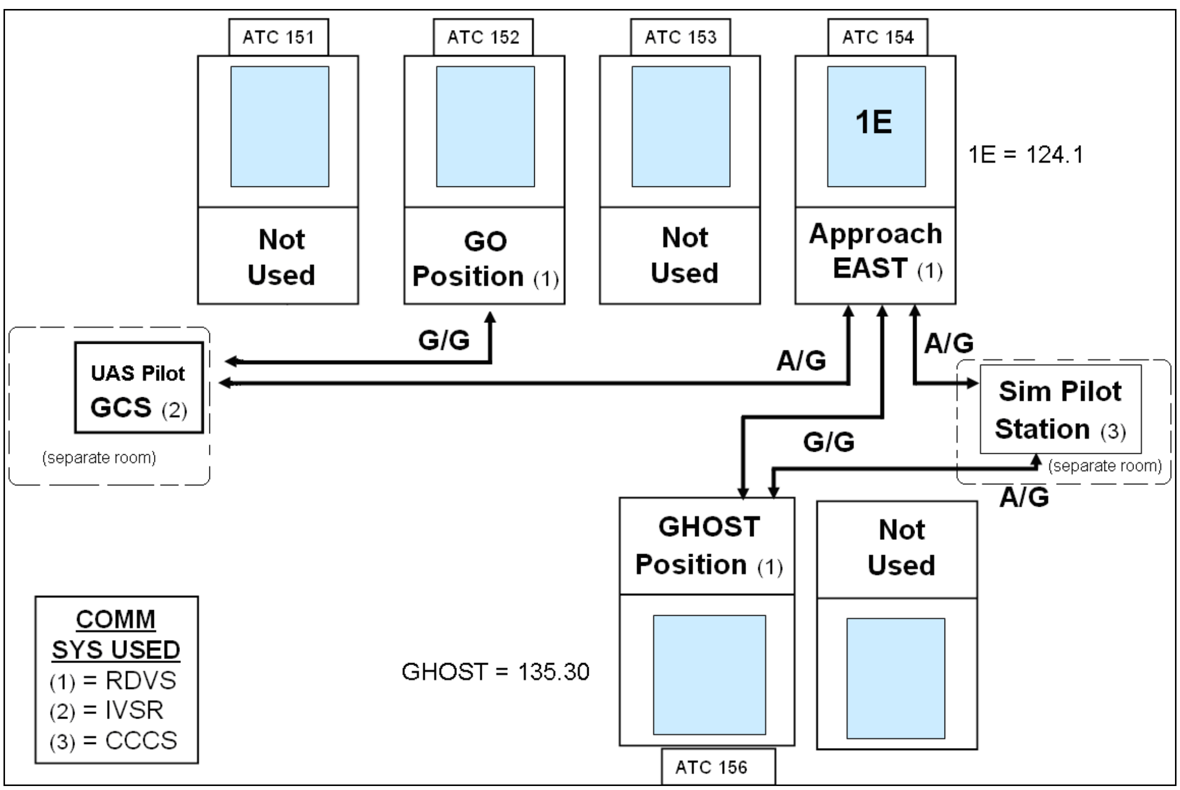

Figure 8. Lab Configuration B
Note: A/G = Air-to-Ground, G/G = Ground-to-Ground

Modified Procedure Synopsis for Configuration A:

- The GO should communicate with ATC:
  - Synopsis of non-cooperative aircraft
  - What threats are holding the UAS from transit
  - Estimated time until transit
- When transit permission is given, include traffic synopsis that may be of consideration: Example: “Transition approved. Traffic in pattern at Morehead and one aircraft north of EWN transiting to the Northeast.”
- ATC can query GO for clarification
- UAS Pilot can query ATC if holding/traffic information isn’t communicated

Modified Procedure Synopsis for Configuration B:

- Responsible for the decision to transit, the GO should communicate:
  - Synopsis of non-cooperative aircraft
  - What threats are holding the UAS from transit
  - Information on cooperative aircraft that are of concern for transit
  - Estimated time until transit
- When transit permission is given, include traffic synopsis that may be of consideration: Example: “Transition approved. Traffic in pattern at Morehead and one aircraft north of EWN transiting to the Northeast.”
- Provide traffic updates if threat appears to be a conflict:
  - e.g., “Threat now 7 miles South of transit volume heading North”
  - e.g., “Traffic no longer a factor, threat passed behind you”

2.6.3 Scenarios

Scenarios were developed from information, analyses, flight plans, and field data provided by the MCAS ATC facility and the US Navy OSF. This data allowed for the replication of NKT’s operational maps and adaptation, and for the development of realistic air traffic scenarios used in the simulation.

The air traffic developed for these scenarios emulated moderate to busy traffic situations for the selected environment. The scenarios were designed in a manner that represents typical traffic density, mix, and flow that occur in the airspace simulated. The traffic mix operating in the simulated environment consisted principally of military, commuter, and general aviation traffic.

One training scenario and four base data collection scenarios were developed for the simulation. The training scenario was approximately 15 minutes in duration and the scenarios used to collect data were approximately 25 minutes in duration. Each base data collection scenario was run in each of three wind conditions, and with two operational configurations described further in section 2.7.1 (see Table 1). Additionally, a “VFR popup” scenario, ran as scenario 4, in which a non-cooperative aircraft appeared on the GO scope approximately three miles from the transit area border, was conducted in both configuration A and configuration B. Thus, a total of 20 data collection experimental runs were to be run in the study. However, because of a weather-related power loss causing difficulty with experimental hardware, runs 15, 17, and 18 (runs S1W0A, S2W0A, and S3W25U, respectively) were not conducted.

Table 1. Scenarios Used in the Study

	Configuration A (GO with ATC)			Configuration B (GO with UAS)		
Wind / Base	0 kts	15 kts	25 kts	0 kts	15 kts	25 kts
Scenario 1	S1W0A*	S1W15A	S1W25A	S1W0U	S1W15U	S1W25U
Scenario 2	S2W0A*	S2W15A	S2W25A	S2W0U	S2W15U	S2W25U
Scenario 3	S3W0A	S3W15A	S3W25A	S3W0U	S3W15U	S3W25U*
Scenario 4	S4W0A	n/a	n/a	S4W0U	n/a	n/a

* = run not conducted

2.6.4 Informed Consent

An informed consent form was read and signed by each participant prior to the commencement of the experiment (see Appendix A).

2.6.5 Biographical Questionnaires

An appropriate biographical questionnaire was completed by each participant before the experiment. The participants provided general information about themselves, including their level of operational experience, on this questionnaire (see Appendix B).

2.6.6 Post-Run Questionnaires

After completing each experimental run, the participants answered questions about the operations they just experienced and provided subjective ratings about their own performance, workload, and situation awareness by entering ratings on a seven-point scale on the applicable Post-Run Questionnaire (PRQ) for their role (see Appendix C). The participants also had the opportunity to provide open-ended responses, which included any information about the experimental run they considered relevant In addition to the PRQ, the participants completed a Situational Awareness Rating Technique (SART) form (see Appendix D).

2.6.7 Subject Matter Expert Observer Forms

SME members of the research team sat behind the ATC, GO, and UAS Pilot participants during each run of the simulation. They used SME Observer Forms (see Appendix E) to collect supplemental information concerning the operations and participants' actions in the performance of their duties.

2.6.8 Post-Experiment Questionnaires

The participants completed a Post-Experiment Questionnaire (PEQ) after completing the entire experiment (see Appendix F). On the PEQ, the participants were given the opportunity to provide their opinions and observations of the proposed operational concept. Using seven-point rating scales, they also answered questions regarding general characteristics of the experiment (e.g., realism). Like the PRQ, the PEQ also posed open-ended questions.

2.7 Design

2.7.1 Experimental Design

The design of this experiment, and all procedures used therein, was approved by the FAA's local Institutional Review Board, on November 30, 2009, and placed human participants under minimal risk or no risk, as defined in FAA Order

9500.25. This study employs a 2 (GO paired with ATC, GO paired with UAS Pilot) x 3 (0 kts, 15 kts, or 25 kts right quartering headwind) factorial design. Three base traffic scenarios were run in each of these six conditions; two "VFR popup" scenarios were run in zero knot wind conditions only (see Table 1).

There were two configurations utilized for this simulation. In configuration A, used in half the trials, the GO position was physically located next to the ATC position. In this configuration, the GO position and ATC communicated verbally (i.e., by simply speaking out loud) without the use of any communication system (see Figure 7). In configuration B, the GO position was remotely located from both the ATC and UAS Pilot positions. In this configuration, ATC and the GO position did not communicate with each other directly; rather, the GO position communicated with the UAS Pilot via a ground-to-ground connection communication system (see Figure 8). A partition blind was used to occlude physical view and communication between the ATC and GO positions in configuration B. In both configurations, the UAS GCS and Simulation Pilot Stations each were located in laboratory rooms physically separate from the ATC, GO, and ghost controller stations (i.e., the study utilized three laboratory rooms).

2.7.2 Dependent Variables

2.7.2.1 ATC System Performance Measures

Many system performance measures for the sector involved in the study were collected. The performance measures analyzed are described in Table 2.

Table 2. ATC and GO System Metrics

ATC System Performance Metrics		
Data Type	**Data Capture**	**Comment**
Average number of aircraft (sector)	During each run	
Number of aircraft handled	During each run	
Number of altitude changes	During each run	For all a/c on ATC's frequency
Number of heading changes	During each run	For all a/c on ATC's frequency
Number of airspeed changes	During each run	For all a/c on ATC's frequency
Number of handoffs	During each run	
Time of transition approval	During each run	Audio recordings
Safety		
Data Type	**Data Capture**	**Comment**
Loss of Separation	During each run	Overall count
Duration of each Loss of Separation	During each run	In seconds
Frequency of conflict alerts	During each run	
Communications		
Data Type	**Data Capture**	**Comment**
Time for GO to communicate transit decision to "second" position	During each run	(to appropriate position) In seconds
"Dead air" lag between communications	During each run	In seconds
Time for "second" position to communicate transit decision to "third"	During each run	In seconds
Time to communicate transit completion	During each run	(to appropriate position(s)) In seconds

2.7.2.2 UAS System Performance Measures

Many system performance measures for the UAS were recorded. The analyzed measures and the sources for those measures appear in Table 3.

Table 3. UAS Objective Data Summary

UAS System Performance Metrics		
Data Type	**Data Capture**	**Comment**
Minimum Separation Distance for any conflicts involving RQ-7B Shadow simulator	During each run	RQ-7B Shadow simulator output data
Number of separation violations for any conflicts involving RQ-7B Shadow simulator	During each run	RQ-7B Shadow simulator output data
Latency from decision to transit to UAS reaching transit volume	During each run	During each run
Duration of time to transit the transit volume	During each run	RQ-7B Shadow simulator output data

2.7.2.3 Subject Matter Expert Observer Data

SMEs that are members of the research team sat behind the ATC, GO, and UAS Pilot participants during each run of the simulation. They used SME Observer Forms (see Appendix E) to collect supplemental information concerning the operations and participants' actions in the performance of their duties. SMEs rated workload and complexity of runs, observed whether procedures were followed, and commented on anomalies during each experimental run.

2.7.2.4 Workload and Situational Awareness

Subjective participant workload ratings were recorded at 2-minute intervals during all runs using the WAK. Situational awareness was measured after each run by using a SART form (see Appendix D).

2.8 Procedure

2.8.1 Experimental Run Order and Position Rotation

The data collection runs were presented in a quasi-random order to ensure that traffic conditions, wind, and operational configuration appeared in a non-systematic manner. The run order is presented in Table 4. Runs 15, 17, and 18 (conditions S1W0A, S2W0A, and S3W25U, respectively) were not conducted due to a weather-related power loss that caused difficulty with experimental hardware. Controller participants (labeled as participants P5 and P6) alternated between ATC and GO roles at pre-determined intervals that are listed in Table 4.

Table 4. Experimental Run Order and Position Rotation

Run #	Condition	GO Rotation	ATC Rotation
1	S3W0A	P5	P6
2	S2W15A	P5	P6
3	S3W15A	P6	P5
4	S2W0U	P6	P5
5	S1W0U	P5	P6
6	S3W0U	P6	P5
7	S1W15A	P6	P5
8	S2W15U	P5	P6
9	S1W25U	P5	P6
14A	S4W0U	P6	P5
10	S1W25A	P6	P5
11	S2W25U	P6	P5
12	S1W15U	P6	P5
13	S3W15U	P5	P6
14	S2W25A	P5	P6
16	S3W25A	P6	P5
9A	S4W0A	P6	P5

2.8.2 General Schedule of Events

The general schedule for the simulation is shown in Table 5.

Table 5. Master Schedule

<table>
<tr><th>Time</th><th>Day 1 (12/1/09)</th><th>Day 2 (12/2/09)</th><th>Day 3 (12/3/09)</th></tr>
<tr><td>8:30</td><td rowspan="6">Welcome, initial in-briefing</td><td rowspan="3">Run 6, Questionnaires</td><td rowspan="10">Unscheduled repair of experimental hardware systems</td></tr>
<tr><td>8:45</td></tr>
<tr><td>9:00</td></tr>
<tr><td>9:15</td><td rowspan="3">Run 7, Questionnaires</td></tr>
<tr><td>9:30</td></tr>
<tr><td>9:45</td></tr>
<tr><td>10:00</td><td rowspan="3">Training Runs (T1 & T2)</td><td rowspan="2">BREAK</td></tr>
<tr><td>10:15</td></tr>
<tr><td>10:30</td><td rowspan="3">Run 8, Questionnaires</td></tr>
<tr><td>10:45</td><td>BREAK</td></tr>
<tr><td>11:00</td><td rowspan="3">Run 1, Questionnaires</td><td rowspan="4">LUNCH</td></tr>
<tr><td>11:15</td><td rowspan="3">Run 9, Questionnaires</td></tr>
<tr><td>11:30</td></tr>
<tr><td>11:45</td><td rowspan="3">Run 2, Questionnaires</td></tr>
<tr><td>12:00</td><td rowspan="2">Run 14A (pop-up), Questionnaires</td><td rowspan="3">Run 14, Questionnaires</td></tr>
<tr><td>12:15</td></tr>
<tr><td>12:30</td><td rowspan="4">LUNCH</td><td rowspan="2">LUNCH</td></tr>
<tr><td>12:45</td><td rowspan="3">Run 16, Questionnaires</td></tr>
<tr><td>1:00</td><td rowspan="3">Run 10, Questionnaires</td></tr>
<tr><td>1:15</td></tr>
<tr><td>1:30</td><td rowspan="3">Run 3, Questionnaires</td><td rowspan="3">Run 9A (pop-up), Questionnaires</td></tr>
<tr><td>1:45</td><td>BREAK</td></tr>
<tr><td>2:00</td><td rowspan="3">Run 11, Questionnaires</td></tr>
<tr><td>2:15</td><td rowspan="3">Run 4, Questionnaires</td><td rowspan="5">Post-Experiment Questionnaires / Break</td></tr>
<tr><td>2:30</td></tr>
<tr><td>2:45</td><td rowspan="3">Run 12, Questionnaires</td></tr>
<tr><td>3:00</td><td rowspan="2">BREAK</td></tr>
<tr><td>3:15</td></tr>
<tr><td>3:30</td><td rowspan="3">Run 5, Questionnaires</td><td rowspan="2">Run 13, Questionnaires</td><td rowspan="5">Debriefing / Discussion</td></tr>
<tr><td>3:45</td></tr>
<tr><td>4:00</td><td>BREAK</td></tr>
<tr><td>4:15</td><td rowspan="2">Break / Discussion</td><td rowspan="2">Break / Discussion</td></tr>
<tr><td>4:30</td></tr>
</table>

2.8.3 Simulation Pilot/Ghost Controller Training

Simulation pilots and ghost controllers were trained to assure operationally consistent, accurate, and timely responses to controller instructions and requests. Lectures on the following topics were presented:

1. Study objectives
2. Study methodology
3. Airspace structure
4. Air traffic characteristics
5. Aircraft equipage
6. Controller procedures
7. Anticipated controller actions

Additionally, the simulation pilots and ghost controllers exercised the scenarios for 24 hours over a 3-day period. Particular emphasis was placed on reacting to complex or unusual controller requests and instructions and timely execution of necessary actions. Additionally, simulation pilot performance was monitored and recorded using a Simulation Pilot Observer form (see Appendix G). This form was used only as an internal validity check and is not part of the data analyses.

2.8.4 Participant In-Briefing

Members of the experiment team briefed the participants prior to their entering the laboratory area to participate in the experiment. This briefing included a high-level description of study goals, discussion of the study background, and detailed description of operational procedures. Questions were encouraged and addressed.

2.8.5 Lab Familiarization and Training

Participants were given an opportunity to experience the proposed operations in a practical and realistic medium-high fidelity environment, while SMEs witnessed the events. Verbal instructions were provided by the research team and operational procedures were reinforced as necessary (see Appendix H). Although the simulated environment was configured to emulate NKT Sector 1E, slight differences between this simulated environment and the operational field existed. Controller participants repeated the practice scenario (conducted under configuration A) until they indicated they were comfortable with the environment and procedures. Each practice scenario ran approximately 15 minutes and all controller participants performed both the ATC role and the GO role in the practice environment. Members of the experiment team were present to answer any questions that arose.

2.8.6 Questionnaires

Qualitative information was collected from participants and SME observers through the use of questionnaires and briefings. This information was organized and scrutinized, with the primary focus of evaluating the proposed concept.

Participants (GO, UAS Pilot, and ATC) completed the appropriate Biographical Questionnaire (see Appendix B) during the initial briefing session. The biographical questionnaire solicited information related to experience and other relevant information.

Participants completed a PRQ specific for their position (see Appendix C) after each data collection run. This questionnaire solicited information about workload as well as opinions and ratings about the operations. A SART form to assess situational awareness was included in each PRQ (see Appendix D).

The participants completed the appropriate PEQ at the end of all runs (see Appendix F). This questionnaire solicited information pertaining to an overall assessment of the proposed operations, the level of realism in the simulation environment, and opinions regarding the proposed operations.

2.8.7 Debriefing

An unstructured group debriefing session was held at the end of each day of simulation. All participants and the research team participated. Similarly, a longer debriefing session was held at the end of the final day of simulation. Debriefings allowed participants to express information not captured by questionnaires, as well as to gain further insight regarding the purpose and scope of the study. All debriefings were audio recorded.

2.8.8 Data Analysis

This research endeavor was purposely designed to be a limited scope HITL exercise. The focus was to explore and refine a site-specific concept under development for UAS operations at MCAS Cherry Point. Due to the limited scope of the study, the data obtained do not meet standards of statistical rigor (i.e., there is limited power for the use of statistical data analysis), nor can it validate the operations or technology proposed in the ConEmp (US Navy, 2008). Rather, this exercise provides an opportunity for early visualization of the proposed concept and a glimpse of information concerning the impact of the proposed operation (including human operators) on the NAS. It is duly acknowledged that the data sample of observations is small and participants are minimal in number. Because this is a study with acknowledged limitations, all data and results are interpreted and presented with due caution. Results cannot be generalized to the population of interest nor accepted as conclusive.

3. Results

3.1 Biographical Questionnaire

The UAS Pilot participant was qualified to operate an RQ-7B Shadow at the time the experiment was conducted. This participant reported 500 total hours experience as a UAS Pilot and 1,000 hours flight crew experience for the RQ-7B Shadow. Within the 12 months preceding the experiment, the Pilot participant had served 25 hours as a UAS pilot, and 20 hours as the crewmember position referred to by the USMC as a “Mission Payload Operator.” This participant was also qualified to fly an RQ-2B Pioneer and ScanEagle UAS. This participant rated his UAS Pilot experience as 7, his computer experience as 7, and his simulator experience as 6 (on a 7-point scale, on which 7 equates with “very experienced”).

The two air traffic controller participants (and on alternating runs, GO participants) reported an average total of 7 years, 5 months of controller experience (civilian and military). Both participants reported actively controlling air traffic in each of the preceding 12 months prior to the experiment. They rated their motivation to participate in the study an average of 6.5 on a 7-point scale (1 = very unmotivated, 7 = very motivated). Both listed their rating/qualification as

“Approach Controller.” One participant held this qualification for one month; the other for one year. These participants had been involved with UAS traffic for an average of 3 years, 8 months. Both listed the Predator as the only UAS they have worked, and reported having this experience once in a typical month. Both participants listed UAS operational experience in military operations in theater, as well as at MCAS Cherry Point. Both reported they had received briefings on UAS performance and operations prior to working UAS traffic. On average, these participants estimated the percentage of traffic they had recently controlled during the time frame in which the experiment took place was:

- General Aviation : 15%
- Commercial (Air carrier, air taxi, etc.) : 10%
- Military (manned): 72%
- Military (unmanned): 3%

3.2 Questionnaire and WAK data

3.2.1 Simulation Realism

The UAS Pilot and controller participants agreed that the simulation was realistic. For overall environment realism, the three participants’ ratings averaged 5.6 (1 = very unrealistic, 7 = very realistic). Similarly, the GO/ATC realism ratings for the simulated air traffic averaged 5.5 on this scale.

3.2.2 Position Differences

Differences were observed after comparing data obtained from ATC, UAS Pilot, and GO positions. All “position differences” of 7-point scale items from PRQ were analyzed by separate Analyses of Variance (ANOVA) conducted for each question. It is important to note that anchors for the 7-point scales varied by individual question; see Appendix C for specifics. A number of position differences were noted in the PRQ. Most notably, the ATC participant reported greater difficulty, greater workload, greater variability, greater complexity, lower spare capacity, and lower division of attention than either the GO or UAS Pilot participant. Means, standard errors, and significance levels appear in Table 6.

Table 6. Position Effects, by Configuration, on 7-point Scale Questionnaire Items

ATC Position

Dimension	Configuration A Mean	Configuration A Std Error	Configuration B Mean	Configuration B Std Error	*p*
Confidence in transit	5.63	0.495	5.78	0.467	0.83
Difficulty	3.75	0.398	3.78	0.376	0.96
Sense of safety	4.38	0.237	4.11	0.224	0.43
Workload	4.75	0.338	4.55	0.319	0.68
Situational Awareness	6.25	0.310	6.00	0.292	0.57
Instability of the situation	3.75	0.514	3.44	0.485	0.67
Variability of the situation	5.50	0.390	5.56	0.367	0.92
Complexity	5.00	0.352	4.89	0.332	0.82
Arousal	5.50	0.289	5.33	0.272	0.68
Spare Capacity	4.63	0.442	4.78	0.417	0.80
Concentration	5.63	0.318	5.44	0.299	0.68
Division of Attention	5.63	0.258	5.33	0.243	0.47

GO Position

Dimension	Configuration A Mean	Configuration A Std Error	Configuration B Mean	Configuration B Std Error	*p*
Confidence in transit	6.38	0.290	5.11	0.462	0.08
Difficulty	**2.13**	0.338	**1.89**	0.319	0.62
Sense of safety	5.25	0.370	4.11	0.348	0.04*
Workload	**2.25**	0.335	**1.67**	0.316	0.23
Situational Awareness	6.63	0.180	6.67	0.169	0.87
Instability of the situation	3.38	0.645	3.67	0.608	0.75
Variability of the situation	**3.38**	0.568	**3.11**	0.536	0.74
Complexity	**2.75**	0.338	**2.44**	0.319	0.52
Arousal	5.75	0.362	5.56	0.341	0.70
Spare Capacity	**6.25**	0.285	**6.56**	0.268	0.45
Concentration	6.25	0.432	5.89	0.407	0.55
Division of Attention	6.38	0.258	**6.56**	0.243	0.57

NOTE: bold = differs from ATC, $p<.05$, Tukey's HSD; * = $p<.05$

UAS Pilot Position

Dimension	Configuration A Mean	Configuration A Std Error	Configuration B Mean	Configuration B Std Error	*p*
Confidence in transit	6.38	0.299	6.89[a]	0.282	0.23
Workload	**1.88**	0.275	**2.44**	0.260	0.15
Situational Awareness	6.25	0.398	5.78	0.376	0.40
Instability of the situation	3.88	0.463	3.11	0.437	0.25
Variability of the situation	**2.75**	0.205	**3.22**	0.194	0.11
Complexity	**2.88**	0.272	3.33[b]	0.256	0.24
Arousal	6.25	0.412	6.11	0.389	0.81
Spare Capacity	**6.88**	0.206	**6.56**	0.194	0.28
Concentration	5.25	0.275	6.22	0.259	0.02*
Division of Attention	**6.88**	0.085	**7.00**	0.081	0.30

NOTE: bold = differs from ATC; [a] = differs from GO; [b] = Differs from ATC and GO; all Tukey's HSD; * = $p<.05$

Additionally, there were significant position differences with regard to WAK data, $F(2,474) = 154.5$, $p < .0001$. Only WAK prompts for which there was a response made were considered. The GO position recorded WAK ratings that were significantly lower, on average ($M = 1.8$), than those made by the ATC position ($M = 3.6$) or the UAS Pilot position ($M = 3.0$). Average ratings made by the ATC and UAS Pilot did not differ significantly (see Figure 9).

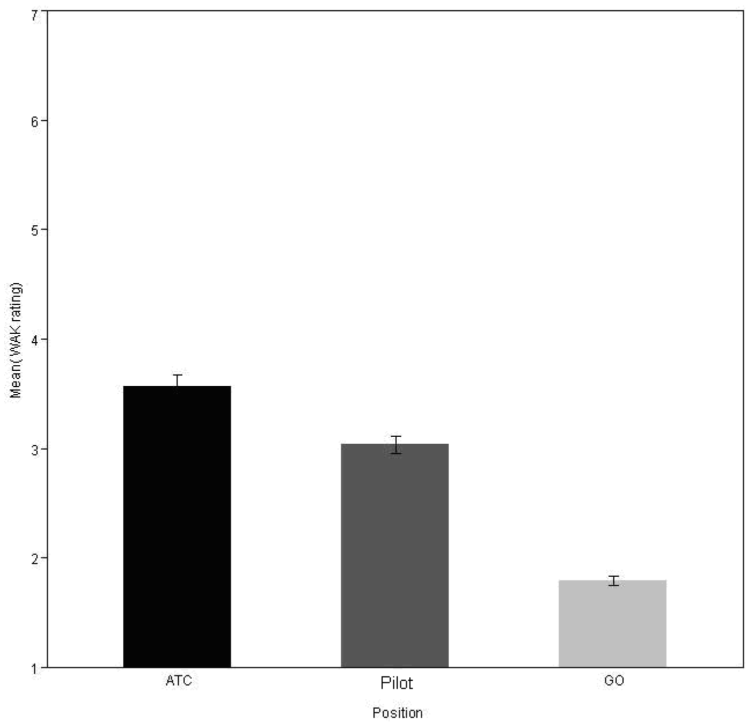

Figure 9. Mean ATC, UAS Pilot, and GO Position Ratings for WAK Workload (Error bars indicate ± 1SE)

An SME recorded that the GO had some difficulty following the new GBSAA-defined procedures and phraseology. However, these individuals were able to "catch on" after a few runs, with discernable improved performance. Participants performing the GO role reported that they were "extremely aware" of the red-yellow-green indicator light, and that it had a positive effect on their awareness of traffic.

Additionally, SME observers reported that the ATC position participants were attentive and cooperative, performed clear concise communication, and maintained separation of all aircraft. However, occasional miscues were noted. In one particular configuration A run, there were three occasions where the ATC focused on the GO display, diverting attention from his own scope (and possibly primary separation responsibilities). Also, in another configuration A run, ATC stated he did not notice some traffic in the transition area on his scope.

In response to open-ended questions, the UAS Pilot reported that in configuration A, all pertinent information was provided by ATC. In configuration B, he reported that he was more likely to ask for a status report (i.e., an estimate of when transit approval might be given) and that he was confident in the GO's situational awareness and ability to grant transit approval when appropriate. More details regarding select open-ended questions are provided in Appendix I.

3.2.3 Configuration Effects

Differences were observed between data obtained from runs conducted in configuration A and configuration B. All configuration effects of 7-point scale questions from PRQ were analyzed by ANOVA. There were no significant effects of configuration on any of the measures for the ATC position (all $p > .05$). However, differences were noted for the GO and UAS Pilot positions.

The GO rated their perception of safety as higher in configuration A ($M = 5.3$) than in configuration B ($M = 4.1$; $F(1,15) = 5.03$, $p < .05$). See Figure 10.

The UAS Pilot reported slightly higher concentration in configuration B ($M = 6.2$) than configuration A ($M = 5.3$; $F(1,15) = 6.63$, $p < .05$). See Figure 11.

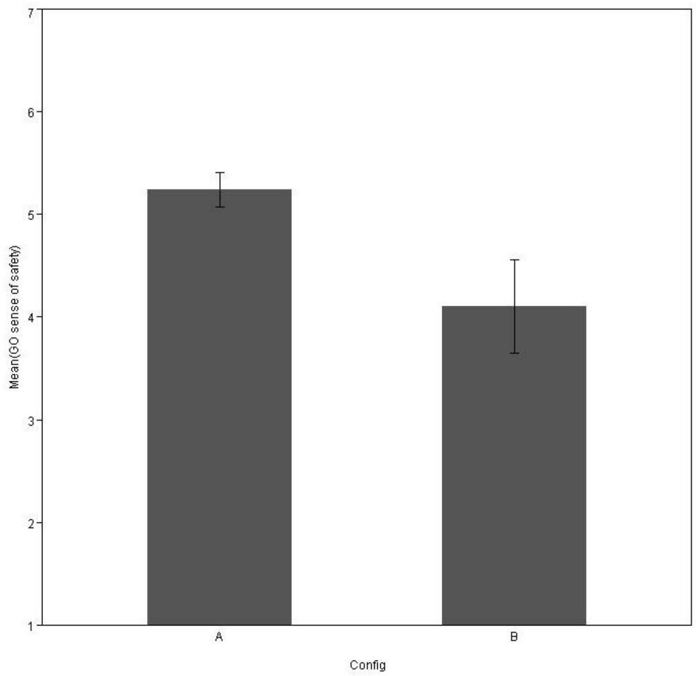

Figure 10. Mean GO Ratings of Sense of Safety
Error Bars Indicate ± 1SE

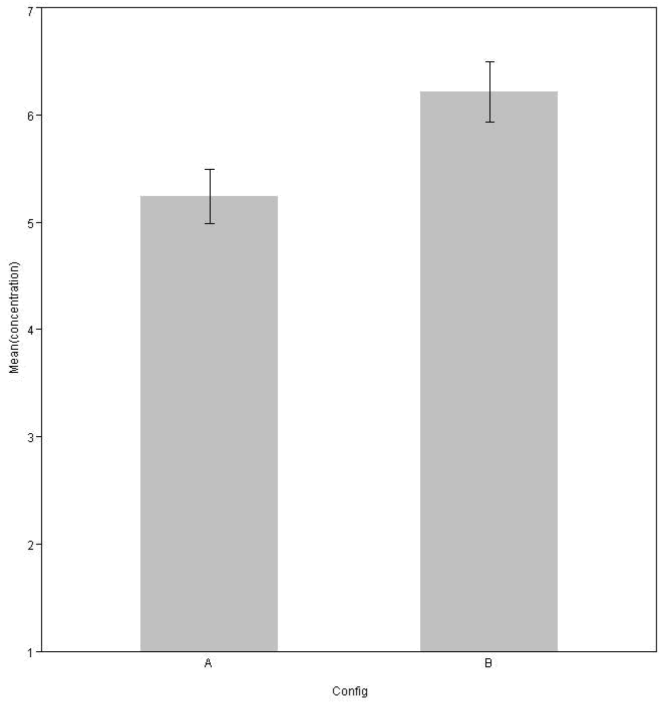

Figure 11. Mean UAS Pilot Ratings of Concentration
Error Bars indicate ± 1SE

For the following analyses, only WAK prompts for which there was a response made were considered. There was no overall effect of configuration on WAK ratings made by ATC (configuration A, *M* = 3.7, SE = .15; Configuration B, *M* = 3.4, SE = .14, $p > .05$). However, effects of configuration on WAK ratings made by the GO and UAS Pilot were observed.

The GO reported higher WAK ratings in configuration A (*M* = 1.9, SE = .06) than in configuration B (*M* = 1.7, SE = .06; $F(1,179) = 4.54$, $p < .05$) and the result was statistically significant. However, it should be noted that while statistically significant, this finding has limited practical implications. A mean difference of .2 on a 7-point rating scale, when both means are less than two, is not an impactful difference, and suggests that in both configurations, the GO experienced rather low workload. Conversely, the UAS Pilot reported greater WAK ratings in configuration B (*M* = 3.5, SE = .10) than in configuration A (*M* = 2.6, SE = .09; $F(1,130) = 42.99$, $p < .05$). The results indicate that the UAS Pilot experienced lower than normal/average workload in both configurations, but more workload in configuration B (see Figure 12).

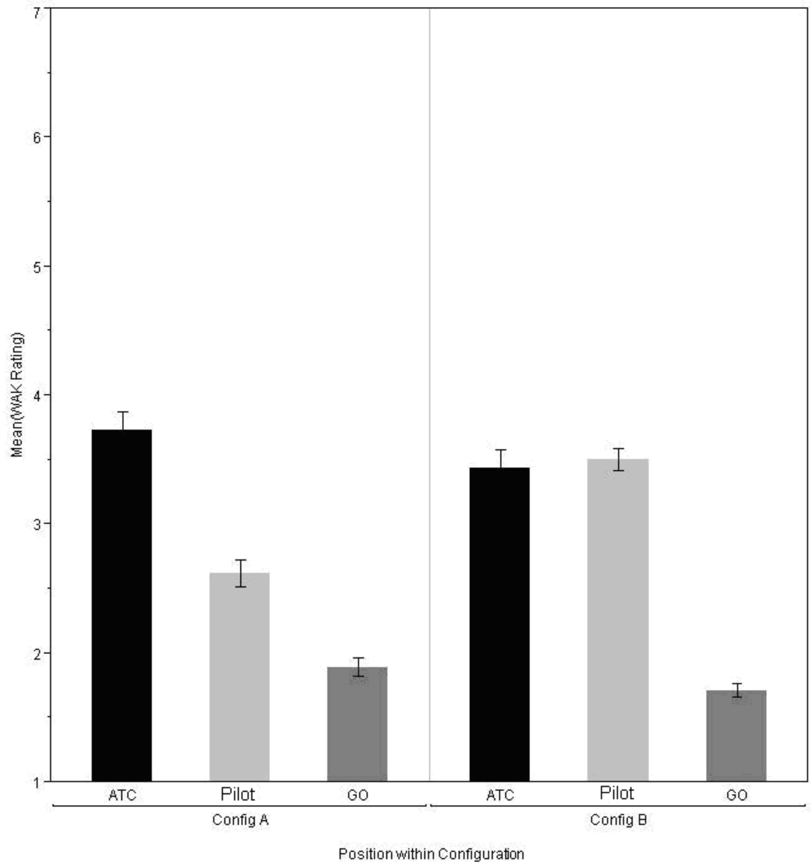

Figure 12. Mean ATC, UAS Pilot, and GO Position
Ratings for WAK Workload, by Configuration
(Error Bars Indicate ± 1SE)

Changes in WAK ratings over time were analyzed by synchronizing the timeline of each experimental run to the transit decision time, setting that time point to zero. From this synchronized timeline, scatterplots of the WAK ratings by time were created for each position (ATC, GO, and UAS Pilot). Fit lines and splines (Lambda = 10,000) were created for each of these scatterplots.

For the ATC and GO positions, an effect of configuration on splines can be seen. For both positions, in configuration A, there is a more “flat” function of WAK rating over time. In contrast, for both positions, in configuration B, there is an increase in WAK rating beginning approximately two minutes prior to the transit decision, leveling off approximately one minute after the transit decision is made. These scatterplots for the ATC position in configuration A and B, and for the GO position in configuration A and B, appear as Figure 13, Figure 14, Figure 15, and Figure 16, respectively.

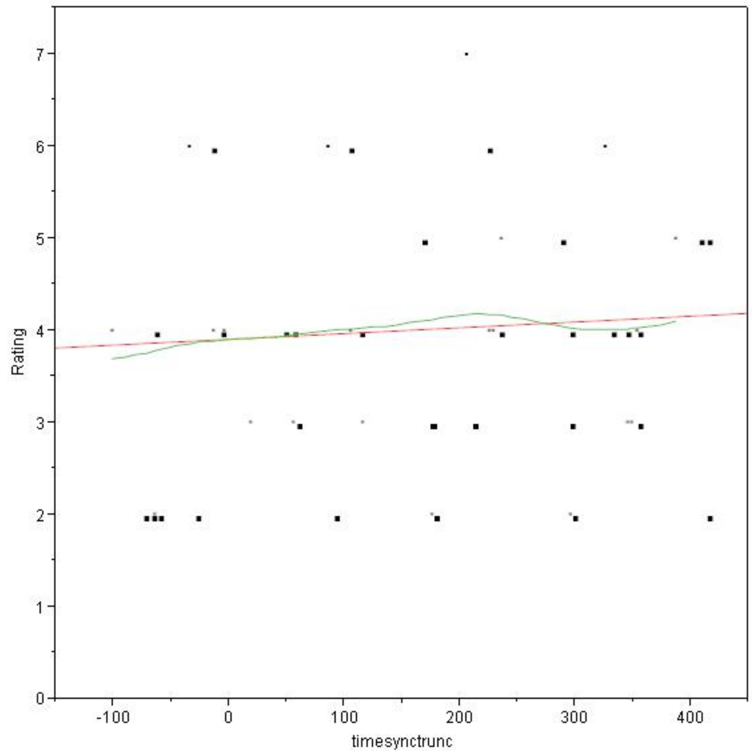

Figure 13. Scatterplot of ATC WAK Ratings Over Time, Synchronized to Transit Decision Time (Configuration A)

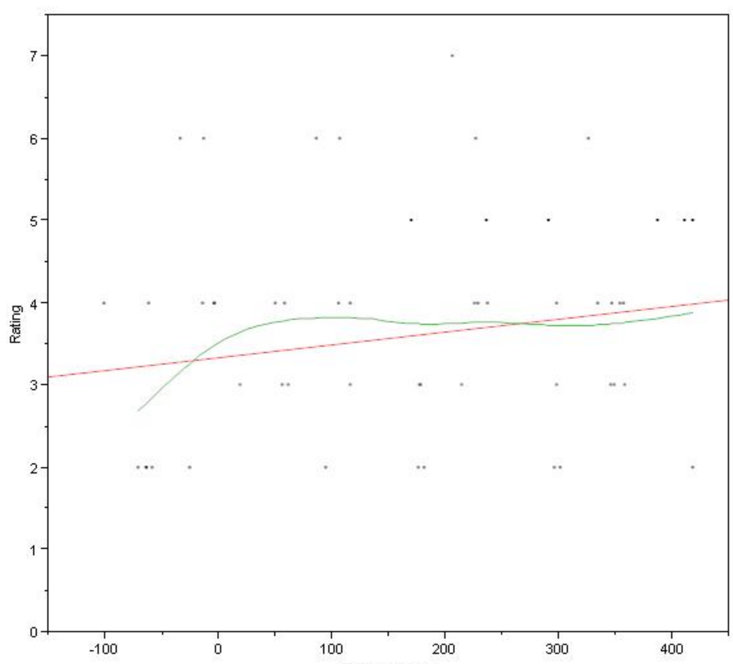

Figure 14. Scatterplot of ATC WAK Ratings Over Time, Synchronized to Transit Decision Time (Configuration B)

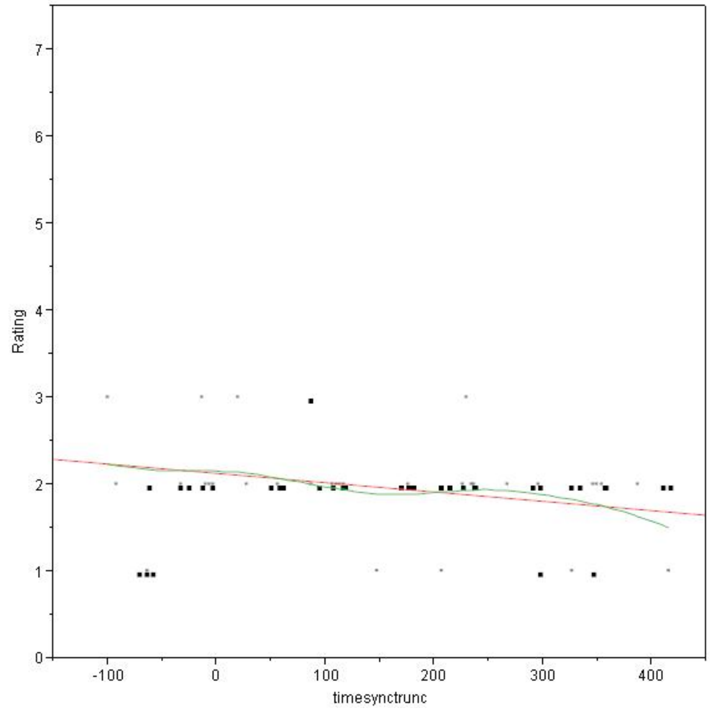

Figure 15. Scatterplot of GO WAK Ratings Over Time, Synchronized to Transit Decision Time (Configuration A)

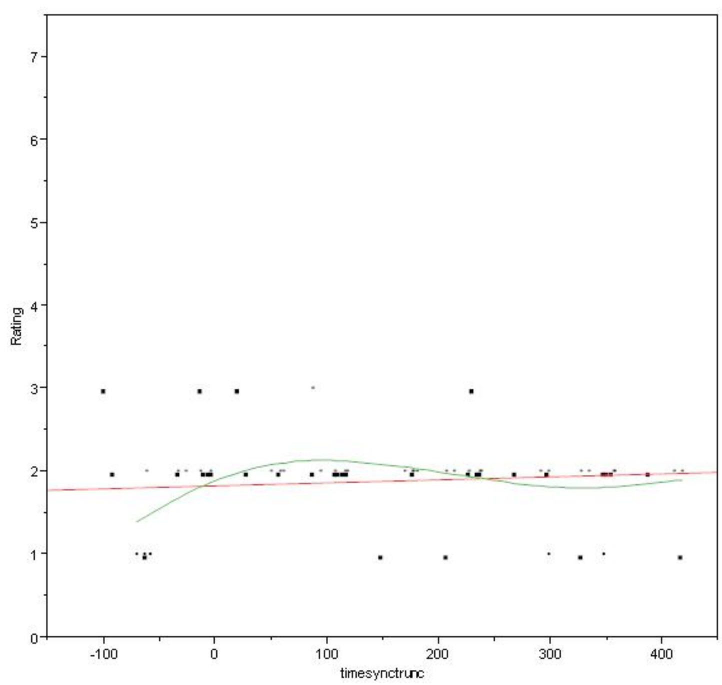

Figure 16. Scatterplot of GO WAK Ratings Over Time, Synchronized to Transit Decision Time (Configuration B)

The opposite effect of configuration on WAK ratings over time was observed for the UAS Pilot position. That is, in configuration B, the UAS Pilot reported a stable WAK rating over time, whereas in configuration A, the UAS Pilot reported an increase in WAK rating beginning approximately two minutes before the transit decision was made, leveling off approximately one minute after the transit decision. Scatterplots for UAS Pilot WAK ratings over time appear as Figure 17 and Figure 18.

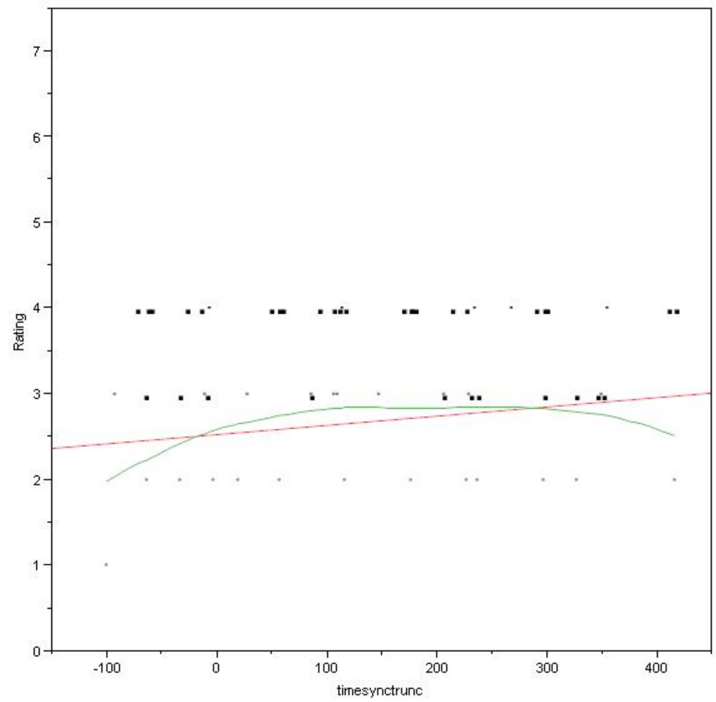

Figure 17. Scatterplot of UAS Pilot WAK Ratings Over Time, Synchronized to Transit Decision Time (Configuration A)

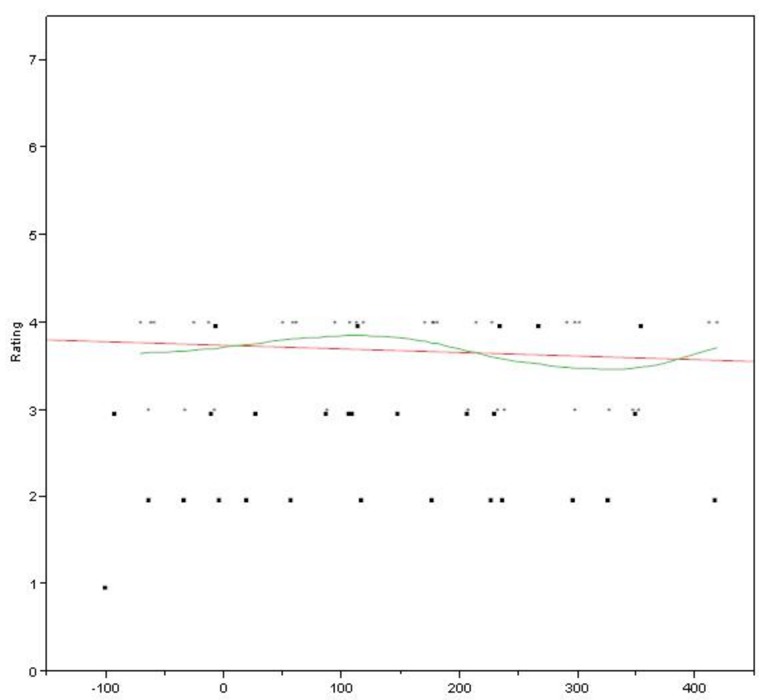

Figure 18. Scatterplot of UAS Pilot WAK Ratings Over Time, Synchronized to Transit Decision Time (Configuration B)

These different patterns for WAK ratings over time as a function of configuration suggest an effect of “being in the loop”. That is, in configuration A, both the ATC and GO positions have greater ease of communication between one another, as they are seated next to each other with direct communication. As such, they may have greater situational awareness: the GO position can easily see the current workload of the ATC position, and can time his communications accordingly, while the ATC position can request a quick update, or even perhaps glance at the GO scope (at least the three-color display indicator), to manage workload effectively. Thus, we observe a “flat” workload function over time for these positions in configuration A, and the workload, perhaps, “hits” these positions with less ability to anticipate the workload demands in configuration B, as seen by the “ramp-up” trend. While this configuration may have helped to anticipate and manage workload changes, it should be noted that it may also involve a distraction effect of diverting attention from the primary responsibility of separating aircraft.

For the UAS Pilot position, the reverse is true. In configuration A, the UAS Pilot position receives a command and executes the transit. In configuration B, the UAS Pilot is much more in the loop, as he is in more frequent communication with the GO position. Thus, in configuration B, he can perhaps anticipate workload demands, and exhibits a “flatter” workload function over time, in contrast to the “ramp-up” trend in configuration A.

3.2.4 Wind Effects

Differences were observed in data collected during experimental conditions simulating different velocities of right quartering headwind. Effects of wind conditions on responses to 7-point scale questionnaire items were assessed by ANOVA, and conducted independently for each questionnaire item. There were no observed robust effects of wind level for the ATC nor UAS Pilot positions. There were two significant effects observed for the GO position. Data from the GO position yielded significant main effects of wind level (i.e., regardless of configuration) on variability of the situation, $F(2,14) = 5.64$, $p < .05$, and workload, $F(2,14) = 3.86$, $p < .05$. A post-hoc Tukey’s HSD test revealed that runs modeling 25 knot winds were rated as having more variability of the situation ($M = 4.8$) than runs modeling 15 knot or 0 knot winds ($M = 2.5$ and 2.7, respectively, both $p < .05$. See Figure 19). Similarly, post-hoc t-tests revealed that runs modeling 25 knot winds were rated as requiring higher workload ($M = 2.8$) than runs modeling 15 knot or 0 knot winds ($M = 1.5$ and 1.7, respectively; both $p < .05$, see Figure 20).

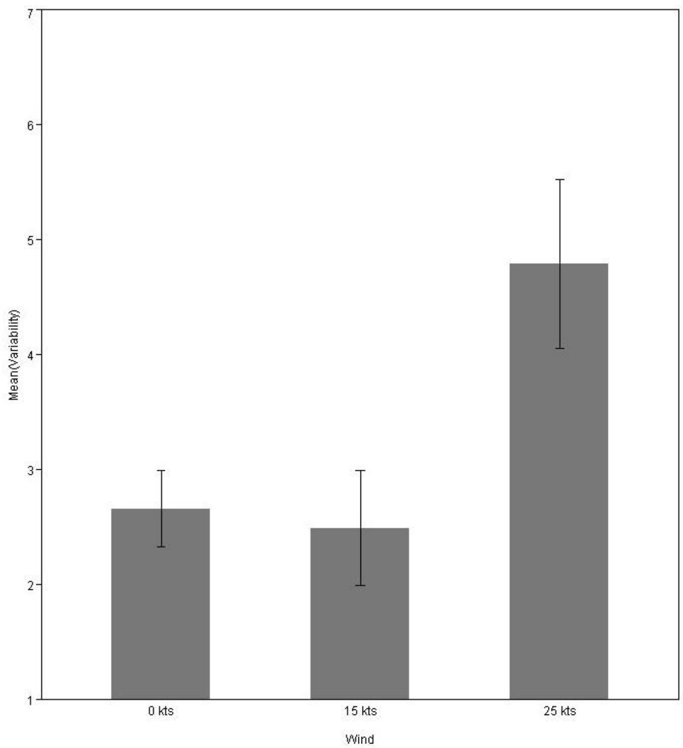

Figure 19. Mean GO ratings of Variability of the Situation, by Wind Condition
(Error Bars Indicate ± 1SE)

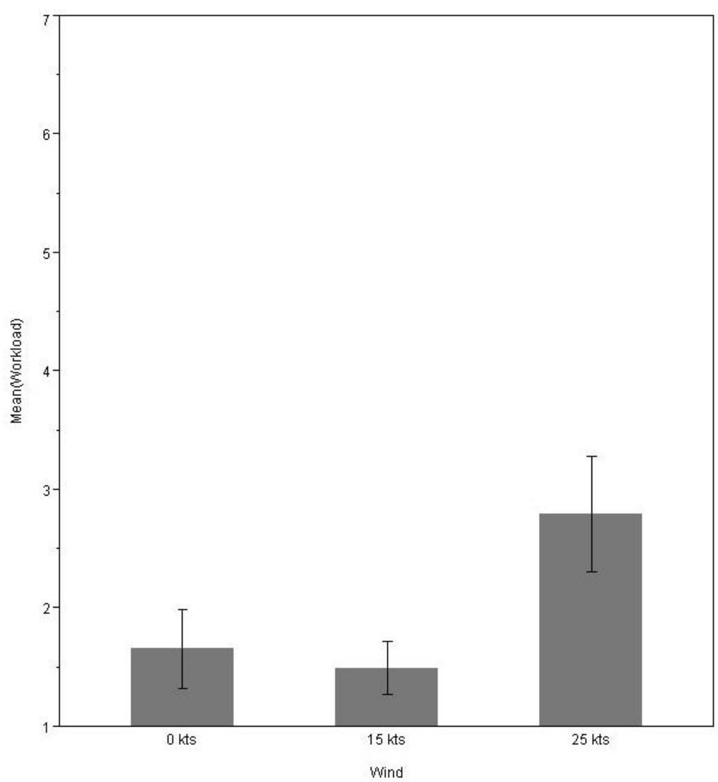

Figure 20. Mean GO Ratings of Workload, by Wind Condition
(Error Bars Indicate ± 1SE)

The effect of wind condition on WAK ratings was assessed using ANOVA. For the ATC position, there was no significant effect of wind on WAK ratings, $F(2,163) = 2.12$, $p = .12$. For the GO position, there was a statistically significant, effect of wind on WAK ratings, $F(2, 180) = 14.33$, $p < .001$. Congruent with the effect of wind reported by the GO on workload as measured by the questionnaire (reported above), a post-hoc Tukey's HSD test revealed that the 25 knot wind condition yielded average WAK ratings (M = 2.1) that were greater than those in 15 knot winds ($M = 1.7$) and zero knot winds ($M = 1.6$).

However, while statistically significant, these mean differences of .4 and .5, on a 7-point scale, do not likely have practical implications. Similarly, a statistically significant effect of wind was observed for the UAS Pilot participant, $F(2,131) = 3.33$, $p < .05$. A post-hoc Tukey's HSD test revealed that average WAK ratings in the 25 knot wind condition ($M = 2.8$) were significantly lower (in contrast to the GO position's lower ratings in 25 knot winds) than those recorded during 15 knot winds ($M = 3.2$). Average WAK ratings recorded in zero knot wind conditions ($M = 3.1$) did not differ significantly from those made in 15 knot or 25 knot wind conditions (see Figure 21 below). Again, while statistically significant, the magnitude of this mean difference (.4 on a 7-point scale), as well as the nonlinear trend, suggests no practical implication from the effect of wind on these workload ratings.

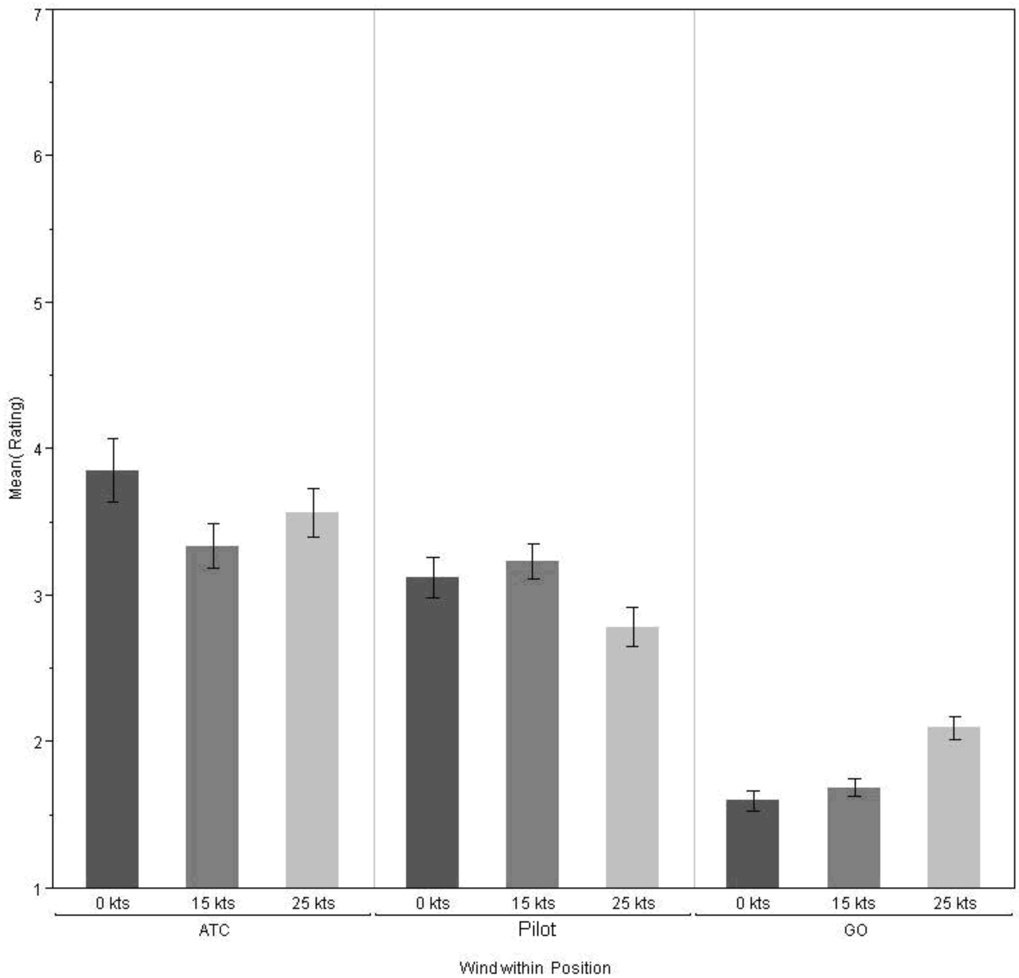

Figure 21. Mean ATC, UAS Pilot, and GO
Position Ratings of WAK Workload, by Wind Condition
(Error Bars Indicate ± 1SE)

3.2.5 Effects of Modified Procedures

During the course of the simulation, at the request of the research team, a change was made, such that a small subset of the runs in the study were conducted with modified procedures. This created a prominent issue regarding the analysis of the data. There were 14 runs conducted with the original procedures, whereas only three runs were conducted with the modified procedures. This imbalance led to a violation of one of the assumptions of the ANOVA statistical technique, as we observed heterogeneity of variance in the two groups. The following analyses are presented regardless of this violation, merely for the purposes of exploring the data.

No significant effects of the modified procedures were observed for the ATC position on any questionnaire item. However, a number of effects on responses made by the GO were noted. The GO position reported greater communication workload (M = 5.0 for modified procedures, M = 1.64 for original procedures, $F(1,15) = 24.26$, $p < .001$), greater difficulty (M = 3.3, M = 1.7, $F(1,15) = 12.91$, $p < .01$), greater workload (M = 3.7, M = 1.6, $F(1,15) = 39.73$, $p < .001$), greater instability of the situation (M = 5.7, M = 3.1, $F(1,15) = 7.43$, $p < .05$), and greater division of attention (M = 6.6, M = 5.7, $F(1,15) = 9.1$, $p < .01$) during the modified procedures, relative to the original procedures. It may be worth noting that two additional questionnaire items approached significant levels regarding the effect of the modified procedures: the GO position reported greater variability of the situation (M = 4.7, M = 2.9, $F(1,15) = 3.54$, $p = .08$), and less spare mental capacity (M = 5.7, M = 6.6, $F(1,15) = 3.75$, $p = .07$) during the modified procedures, relative to the original procedures.

Effects of the modified procedures on workload (as indicated by WAK ratings) were observed for the GO and UAS Pilot positions, but not for the ATC position. The GO reported greater workload during the modified procedures compared to the original procedures (M = 2.5 and 1.7, respectively, $F(1,179) = 60.32$, $p < .05$). The UAS Pilot showed the opposite effect of the modified procedures on workload, reporting less workload during the modified procedures than the original procedures (M = 3.3 and 2.0, respectively, $F(1,130) = 70.1$, $p < .05$). None of these WAK ratings express greater than "average" or "typical" workload as defined on the scale, as was the case for those ratings when original procedures were employed.

3.3 Traffic Data

The TGF system recorded objective traffic data for the Approach East Sector. These data are presented below as a means of characterizing traffic and controller workload in our experimental runs.

The following data describe all experimental runs, excluding the two shorter duration VFR pop-up runs. The mean number of aircraft handled by the ATC participant was approximately 19. These aircraft were handled for an average duration of approximately 13 minutes per aircraft. These runs involved an average of approximately 16 altitude commands, 11 heading commands, less than one airspeed command, and 19 handoffs.

The two VFR pop-up runs were approximately 10 minutes shorter in duration, and thus are described separately below. The mean number of aircraft handled in these runs was approximately 11. These aircraft were handled for an average duration of approximately six minutes per aircraft. These runs involved an average of approximately three altitude commands, six heading commands, and seven handoffs.

3.4 Transit and Communication Timeline

During each run, human response latencies were observed via audio and video recording. Mean latencies for each phase of the communications pathways, which were different between configuration A and configuration B, appear in Table 7.

Table 7. Transit Timeline, in Configuration A and Configuration B

CONFIGURATION A	Average	Standard Error
Time from GO decision to Pilot copying that decision	2.3 s	0.6
"Dead air" lag between communications	2.4 s	0.8
Time from ATC contacting Pilot to Pilot copying transit decision	7.1 s	1.1
Transit time from holding to edge of transit volume	62.2 s	24.4
Transit time through transit volume	4 m, 36 s	34.8 s
Time from Pilot reporting completion to ATC to ATC copying that report	8.3 s	0.8
CONFIGURATION B		
Time from GO decision to Pilot copying that decision	5.7 s	1.4
"Dead air" lag between communications	17.1 s	12.4
Time from Pilot reporting transit to ATC to ATC copying that report	32.8 s	11.6
Transit time from holding to edge of transit volume	58.7 s	19.0
Transit time through transit volume	4 m, 27 s	21.6 s
Time from Pilot reporting completion to ATC to ATC copying that report	14.0 s	4.2
Time from Pilot reporting completion to GO to GO copying that report	6.8 s	0.8

The mean time for all three positions to be informed of a transit decision was calculated from these values. The effect of configuration on this communication timeline was analyzed by ANOVA. There was a significant effect of configuration on the communication timeline. It took longer for all three participants to be informed of a transit decision in configuration B (M = 55.6 seconds, SE = 13.8) than in configuration A (M = 10.1 seconds, SE = 14.6, $F(1,15) = 5.13$, $p < .05$).

Two experimental runs produced timeline values that are statistical outliers (i.e., the communication timeline was greater than three standard deviations from the mean). If these values are omitted from the analyses, the same pattern of results is reached. That is, it took longer for all three participants to be informed of a transit decision in configuration B (M = 28.4 seconds, SE = 3.7) than in configuration A (M = 10.1 seconds, SE = 3.5, F(1,13) = 12.74, p < .05).

However, it is important to note that both outliers occurred during configuration B conditions. In both of these runs, the communication timeline was over 100 seconds, as the ATC position had to clarify communication procedures with the UAS Pilot during communication. For example, in one of these outlier runs, the UAS Pilot requested transition from ATC; ATC responded by asking the UAS Pilot if he had received permission from the GO; the UAS Pilot replied that he had. ATC then advised the UAS Pilot to proceed as previously informed by the GO, indicating a misunderstanding of the procedures. Similarly, evidence from participant written responses and comments from SMEs suggest that the UAS Pilot was unsure of the configuration B procedures. He continued to revert to what he considered "his routine of what he was used to in his field environment" of working with a crew led by a Mission Commander who communicated with ATC.

Additionally, during the VFR popup runs, the participant operators reported notable difficulty in performing their tasks. Following a configuration A run, an ATC participant wrote, "When the target popped up, the time it took for me to get the report [from the GO], look to see the possible threat [on the GO scope] and to give the most accurate call to the UAS, could have easily affected the flow of traffic to other aircraft. If it were in configuration B, to the controller, it would not have had an effect."

The average elapsed time while the RQ-7B Shadow traversed the transit volume was approximately 4 minutes 30 seconds (see Table 7). In some cases, the RQ-7B Shadow was in holding as far as possible from the transit volume's border, and oriented away from the volume. It is worthwhile to note that, on average, approximately one additional minute (ranging from 0 seconds to approximately 2 minutes 30 seconds) elapsed while the RQ-7B Shadow moved from its holding pattern to the edge of the transit volume. However, during this additional minute, the RQ-7B Shadow was in a safe state within the Class D Airspace. The RQ-7B Shadow was only transitioning through NAS airspace for an average of 4 minutes, 30 seconds.

3.5 Safety Metrics

In 16 of the 17 experimental runs, a successful UAS transition was completed. In one experimental run, a "successful non-transition" occurred. That is, in the non-transition run, the GO determined that conditions were not met to safely transit and successfully held the RQ-7B Shadow in a safe state within the Class D Airspace.

At no point in the simulation was there loss of separation between any aircraft; this includes the RQ-7B Shadow. There were three ATC system-generated conflict alerts during the experiment; all were between two manned aircraft. Two alerts occurred during the same run (characterized by Scenario 1, zero winds, configuration B conditions). These warnings lasted for 88 and 138 seconds, respectively. However, these conflict alerts involved a VFR aircraft, for which only an advisory role from ATC is required. The third alert occurred during a Scenario 2 run in the zero wind, configuration B condition. This warning lasted for 83.5 seconds. As stated above, none of these conflict alert warnings resulted in a loss of separation.

4. Discussion

It is important to recognize that this study was, by design, limited in scope and exploratory in nature. Results were derived with the minimum number of participants possible and limited observations. In most cases, there is insufficient statistical power to make a statement regarding the absence of a significant effect (however, all significant effects in this report were observed in spite of this limited power). In the case of the analyses investigating the effects of modified procedures, extra care should be taken in interpreting the results, as a critical assumption of the ANOVA technique was violated. Furthermore, this study was an operational assessment of the proposed operations, and did not incorporate elements of the proposed hardware nor the algorithm of the GBSAA decision support tool. Due to the (known and intentional) lack of a representative sample of participants, these results should not be generalized to the population of interest (i.e., Controllers and UAS Pilots at MCAS Cherry Point, nor the greater population potentially interacting with UAS). In short, this study provides a brief, initial look at the proposed operations at MCAS Cherry Point.

In regard to realism, all participants rated both the overall simulation environment and the traffic presented in the scenarios as realistic. The operations, in general, yielded safe transit of the RQ-7B Shadow. With regard to safety, the GO position rated his sense of safety of the transit as greater in configuration A. However, at no point in the simulation was there loss of separation between any aircraft, including the RQ-7B Shadow. In 16 of the 17 runs conducted, a successful transition was completed; on one run, a successful “non-transition” occurred. For this run, the GO determined that traffic conditions did not permit transition of the UAS through the transit volume, and successfully held the RQ-7B Shadow in its safe state within the Class D Airspace.

Workload metrics suggest that no role during this simulation was unmanageable. Some workload differences were observed between ATC and GO positions, and between configuration A and configuration B; however, average workload was nearly always reported as below “normal.” This supports the premise that the proposed GO position does not appear to be more workload-intensive than a typical ATC position, and the impact of working with the GO did not adversely affect ATC workload.

In regard to the GO position, ad hoc discussions between participants and SMEs during the debriefing session suggest that the GO position would be best staffed by an individual with some subset of ATC skills, who would not necessarily need to be a full performance level ATC. Participants stated that with proper training and adaptation “almost anyone could make the appropriate call as a GO,” as this position owns no airspace, has minimal workload, and serves in an advisory role.

Some effects of configuration were observed. The UAS Pilot participant rated concentration and WAK workload as greater in configuration B than configuration A; as previously mentioned, the GO position rated sense of safety as greater in configuration A. However, observations collected in the qualitative data and debriefings suggest that no strong preference was felt for one configuration over the other by any of the participants. Ultimately, all participants suggested that a modified version of configuration B, in which, importantly, there would be a direct line of communication between the GO and ATC positions, would be best.

Different pathways of communication were explored by using two experimental configurations with unique procedures (called configuration A and configuration B). There were large configuration effects on the timeline to communicate the GO decision to transit the UAS. Configuration B took nearly five times as long (i.e., nearly a minute), relative to configuration A, to communicate the decision to transit the RQ-7B Shadow to all three participants. However, it was learned during the simulation that the UAS Pilot participant had very limited experience communicating directly with ATC. Rather, during operations in theater today, a person serving as Mission Commander typically interacts directly with ATC. The UAS Pilot’s lack of familiarity with standard NAS communications was evident, and may have been a factor in the increased communication time observed in configuration B (where the UAS Pilot position communicated with ATC). This increased communication time would likely have been reduced had we observed a UAS Pilot participant who had more training and experience communicating in the NAS environment. It remains unknown what effect the inclusion of a Mission Commander would have had on these communication timelines.

The time required for the RQ-7B Shadow to traverse the transit volume averaged 4 minutes, 30 seconds. However, this finding was affected by two factors: winds aloft and holding status of the RQ-7B Shadow. The UAS Pilot participant (and respective SME) reported difficulty maintaining the required 90 knot ground speed through the transit volume in the 25 knot wind conditions. UAS system data supported this point: the UAS averaged only 77.7 knots ground speed through the corridor in the 25 knot wind conditions. Furthermore, an additional minute, on average, was added to the effective transit time due to the time elapsed during the transit of the RQ-7B Shadow from its position in its holding orbit to the border of the transit volume. In some instances, the total elapsed time from transit decision to transit completion approached seven minutes. In contrast to this important effect of winds aloft on ground speed, there were no impactful effects of wind conditions on questionnaire or WAK rating metrics.

Effects of the modified procedures implemented on the final day of the simulation must, as described in detail above, be interpreted with caution. These modified procedures appeared to have a number of effects on the GO position, notably: increasing general workload, increasing communication workload to slightly above "normal" levels, and decreasing spare mental capacity. The ATC participants generally reported these "modified procedures" as too much information to manage and report. For example, during one particular run, the ATC position stated, "That's too much information to give NITEOWL; I just need to know when he can go." However, the UAS Pilot participant preferred having this extra information regarding traffic and expected hold time.

5. Conclusions and Recommendation

In conclusion, this limited scope operational assessment of the proposed operations at MCAS Cherry Point suggests that the proposed operations were, on the whole, successful. Major observations included no loss of separation between any aircraft, workload was not a substantial issue, and the RQ-7B Shadow made a successful transition in 16 of 17 runs (with one successful "non-transition"). With further refinement of the procedures and algorithm involved, this general concept appears to merit further exploration. Therefore, it is recommended that comprehensive safety and validation studies be conducted when a final operational concept has been developed.

6. Acronyms

6 DoF	Six Degrees of Freedom
A/G	Air-Ground
AGL	Above Ground Level
ANOVA	Analyses of Variance
ATC	Air Traffic Control
COA	Certificate of Waiver or Authorization
ConEmp	Concept of Employment
CRDA	Cooperative Research and Development Agreement
CVA	Central Viewing Area (within the WJHTC)
DESIREE	Distributed Environment for Simulation, Rapid Engineering, and Experimentation
DoD	Department of Defense
EWN	Coastal County Regional Airport
FAA	Federal Aviation Administration
FL	Flight Level
FMS/FCS	Flight Management System/Flight Control System
GBSAA	Ground-Based Sense and Avoid
GO	GBSAA Observer
HILSIM	Hardware-in-the-Loop Simulator
MCALF	Marine Corps Auxiliary Landing Field
MCAS	Marine Corps Air Station
MRH	Michael J. Smith Airport
NAS	National Airspace System
NCA	MCAS New River
NIEC	NextGen Integration and Evaluation Capability
nm	Nautical Mile
NJM	MCALF Bogue Field
NKT	MCAS Cherry Point Airport
PEQ	Post-Experiment Questionnaire
PI	Principal Investigator
PRQ	Post-Run Questionnaire(s)
SAA	Sense and Avoid
SART	Situational Awareness Rating Technique
SME	Subject Matter Expert
STARS	Standard Terminal Automation Replacement System
TGF	Target Generation Facility
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UFIT	UAS FAA and Industry Team
USMC	United States Marine Corps
VFR	Visual Flight Rules
WAK	Workload Assessment Keypad
WJHTC	William J. Hughes Technical Center

7. References

Federal Aviation Administration, Unmanned Aircraft Systems (UAS) Integration Evaluation Plan, Draft Version 4.5 (2009).

US Navy, Cherry Point Concept of Employment at Marine Corps Air Station Cherry Point, Draft Version 0.6 (2008).

Appendix A – Informed Consent Statement

I, ________________________________, understand that this study, entitled "UAS Operational Assessment, Marine Corps Air Station, Cherry Point, NC" is sponsored by the Federal Aviation Administration (FAA) and is being directed by Karen Buondonno, Principal Investigator (PI).

Nature and Purpose:
I have been recruited to volunteer as a participant in this project. The purpose of the study is to measure UAS, UAS Pilot, NAS, GO and ATC performance in a high-fidelity, controller-in-the-loop simulation.

Experimental Procedures:
The participants will work from 8:30 AM to no later than 4:30 PM every day with a 1 hour lunch break and at least 2 fifteen minute rest breaks.

The simulation will be audio and video recorded in case researchers need to reexamine any important simulation events. I hereby agree that all records collected by the research team in the course of this study are available to the research study investigators, support staff, and any duly authorized research review committee. I grant the research team permission to reproduce and publish all records, notes, or data collected from my participation, provided there is no association of my name or identity with the collected data and that confidentiality is maintained, unless specifically waived by me.

Confidentiality:
My participation is strictly confidential, and I understand that no individual names or identities will be associated with the data 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 into the proposed operational concepts for UAS operations in the NAS. My data will help the FAA to establish the feasibility of these procedures within such an environment.

Participant Responsibilities:
I am aware that to participate in this study I must be certified/licensed at my position. During simulation, I will pilot a UAS, act as a Ground-based SAA Observer (GO), or control air traffic and answer questions asked during the study to the best of my abilities. I will not discuss the content of the experiment with anyone until the study is completed.

Participant Assurances:
I understand that my participation in this study is completely voluntary and I can withdraw at any time without penalty. I also understand that the researchers in this study may terminate my participation if they believe this to be in my best interest. I understand that if new findings develop during the course of this research that may relate to my decision to continue participation, I will be informed.

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

The research team has adequately answered all the questions I have asked about this study, my participation, and the procedures involved. I understand that Karen Buondonno (FAA PI) or another member of the research team will be available to answer any questions concerning procedures throughout this study.

If I have questions about this study or need to report any adverse effects from the research procedures, I will contact Karen Buondonno (FAA) at (609) 485-4036.

Discomfort and Risks:
I understand that I will not be exposed to any foreseeable risks or intrusive measurement techniques.

I agree to immediately report any injury or suspected adverse effect to Karen Buondonno at (609) 485-4036. 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 form. 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 form.

Research Participant:_______________________________________ Date:__________

FAA Principal Investigator:_________________________________ Date:__________

Witness:____ Date:__________

Appendix B - Biographical Questionnaires

Biographical Questionnaire – Controller and GO

Participant #:____________ Date:__________

Instructions:
This questionnaire is designed to obtain information about your background and experience. Researchers will only use this information to describe the participants in this study as a group. Your identity will remain anonymous.

The following information is requested for reporting data relevant to the flight tests supporting the RQ-7B Operational Assessment: Marine Corps Air Station, Cherry Point, NC.

Your personal information will be kept completely confidential and will not be included in any of the reports or documents that will be produced as a result of this study. When necessary, individuals will be identified as Participant 1, 2, or 3.

1. How long have you been a Controller (include both civilian and military experience)?

_______Years _______Months

2. How many **of the last 12 months** have you been actively controlling air traffic?

_______Months

3. Rate your level of motivation to participate in this study.

1	2	3	4	5	6	7
No motivation			Moderately motivated			Very motivated

4. What is your ATC rating/qualification (e.g., Approach Controller)?
____

5. How long have you had this qualification? ___________________

6. For how long have you been involved with UAS traffic? _______ Years _______ Months

7. With which model(s) of UAS(s) have you worked? ______________________________
____
____
____

8. How often are you involved with UAS traffic in a typical month? _________________________

9. Please describe the UAS operations which you have had experience with. If some operations are/were classified, please just list as "military operations."
____
____

10. Describe any training/briefings you were given regarding UAS before you were first exposed to UAS operations (not including today).

____
____
____
____
____
____

11. Please estimate the percentage of traffic that you currently control that falls into the following categories:

General Aviation _____%
Commercial (Air carrier, air taxi, etc.) _____%
Military (manned) _____%
Military (unmanned) _____%
Other ______________________ _____%

Biographical Questionnaire – Pilot

Participant #:__________ Date:__________

Instructions:
This questionnaire is designed to obtain information about your background and experience. Researchers will only use this information to describe the participants in this study as a group. Your identity will remain anonymous.

The following information is requested for reporting data relevant to the flight tests supporting the RQ-7B Operational Assessment: Marine Corps Air Station, Cherry Point, NC.

Your personal information will be kept completely confidential and will not be included in any of the reports or documents that will be produced as a result of this study. When necessary, individuals will be identified as Participant 1, 2, or 3.

1. Are you currently certified to operate an RQ-7B? YES / NO

2. How much total experience do you have as UAS PILOT of an RQ-7B?

__________ Hours

3. How much total flight crew experience do you have with an RQ-7B *specifically at Cherry Point*?

__________ Hours

4. Please estimate your hours of flight crew experience with an RQ-7B *(anywhere) for the past 12 months. Also, please list the flight crew position for each (e.g., Mission Commander, MPO).*

Position_______________ __________ Hours
Position _______________ __________ Hours
Position _______________ __________ Hours
Position _______________ __________ Hours

5. Are you currently a certified to fly types of UAS other than RQ-7B? YES / NO

6. Please list the UAS you are certified to fly:

____
____
____
____
____

7. What is your total experience as a Pilot for manned aircraft types?

Hours:_______________ or Not Applicable_______

8. What certificates and ratings do you currently hold for manned aircraft?

____
____
____
____

9. Please rate your experience as UAS PILOT of the RQ-7B.

1	2	3	4	5	6	7
No experience			Moderate experience			Very experienced

10. Please rate your previous computer experience.

1	2	3	4	5	6	7
No experience			Moderate experience			Very experienced

11. Please rate your previous simulator experience.

1	2	3	4	5	6	7
No experience			Moderate experience			Very experienced

Appendix C - Post-Run Questionnaires

Post-Run Questionnaire – Controller

Participant #:	**CONFIGURATION**
Run Number:	**A**
Scenario ID:	
Date: _____/_____/ 2009	**GO paired with ATC**

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

1. Rate your workload for **communications with the GO**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

2. How effective were **communications with the GO**.

1	2	3	4	5	6	7
Very ineffective			Moderately effective			Very effective

3. Rate the **usefulness of information** from the GO in aiding your decision to transit the UAS.

1	2	3	4	5	6	7
Very Useless			Moderately useful			Very useful

4. Rate your **confidence** for the information the GO provided.

1	2	3	4	5	6	7
Very low			Moderate			Very high

5. Rate the **overall difficulty** of these operations.

1	2	3	4	5	6	7
Very easy			Moderate			Very difficult

6. In your opinion, to what extent did the operations in this scenario **affect safety**?

1	2	3	4	5	6	7
Vastly degraded			No effect			Vastly improved

7. Rate the effect of the **wind** in performing these operations.

1	2	3	4	5	6	7
No effect			Moderate effect			Strong effect

8. How did the GO position affect your decision for UAS transit? That is, without the GO, would you have authorized transit earlier, later, or not at all?_____________________________________

____

Post-Run Questionnaire – Controller

Participant #:	**CONFIGURATION**
Run Number:	**B**
Scenario ID:	
Date: _____/_____/ 2009	**GO paired with UAS**

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

1. Rate your confidence level with the UAS transit.

1	2	3	4	5	6	7
Very low			Moderate			Very high

2. Rate the **overall difficulty** of these operations.

1	2	3	4	5	6	7
Very easy			Moderate			Very difficult

3. In your opinion, to what extent did the operations **affect safety**?

1	2	3	4	5	6	7
Vastly degraded			No effect			Vastly improved

4. Rate the effect of the **wind** in performing these operations.

1	2	3	4	5	6	7
No effect			Moderate effect			Strong effect

5. If the decision to transit were yours, would you have approved transit of the UAS earlier, later, or at the same time as just occurred? Please explain.

____
____
____
____
____

6. While the UAS was holding, did you provide any advisories to the UAS PILOT? If yes, please explain.

____
____
____
____

Participant #:	**CONFIGURATION**
Run Number:	**A**
Scenario ID:	
Date: _____/_____/ 2009	**GO paired with ATC**

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

1. Rate your workload for **communications with ATC**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

2. How effective were **communications with ATC**.

1	2	3	4	5	6	7
Very ineffective			Moderately effective			Very effective

3. Rate your confidence level for the UAS transit during this scenario.

1	2	3	4	5	6	7
Very low			Moderate			Very high

4. Rate the **overall difficulty** of these operations.

1	2	3	4	5	6	7
Very easy			Moderate			Very difficult

5. In your opinion, to what extent did the operations **affect safety**?

1	2	3	4	5	6	7
Vastly degraded			No effect			Vastly improved

6. Rate the effect of the **wind** in performing these operations.

1	2	3	4	5	6	7
No effect			Moderate effect			Strong effect

7. To the best of your recollection, did you change any aircraft status from “Yellow” to “Green”?
YES / NO. If “Yes”, to the best of your recollection, describe **why** you made any status changes.

____

____

____

____

____

____

____

8. In the space below, please describe the conditions that led to your decision to approve the UAS transit. That is, **why** did you decide to approve transit when you did?

9. Were there aircraft you would have changed from "Yellow" to "Green", but could not change due to procedure guidance? If there were, please explain.

Participant #:	**CONFIGURATION**
Run Number:	**B**
Scenario ID:	
Date: _____/_____/ 2009	**GO paired with UAS**

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

1. Rate your workload for **communications with the UAS Pilot**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

2. How effective were **communications with the UAS Pilot?**

1	2	3	4	5	6	7
Very ineffective			Moderately effective			Very effective

3. Rate your confidence level for the UAS transit.

1	2	3	4	5	6	7
Very low			Moderate			Very high

4. Rate the **overall difficulty** of these operations.

1	2	3	4	5	6	7
Very easy			Moderate			Very difficult

5. In your opinion, to what extent did the operations in this scenario **affect safety**?

1	2	3	4	5	6	7
Vastly Degraded			No effect			Vastly improved

6. Rate the effect of the **wind** in performing these operations.

1	2	3	4	5	6	7
No effect			Moderate effect			Strong effect

7. To the best of your recollection, did you change any aircraft status from "Yellow" to "Green"?
YES / NO. If "Yes", to the best of your recollection, describe **why** you made any status changes.

____
____
____
____
____

8. In the space below, please describe the conditions that led to your decision to approve the UAS transit. That is, **why** did you decide to approve transit when you did?

9. Were there aircraft you would have changed from “Yellow” to “Green”, but could not change due to procedure guidance? If there were, please explain.

Participant #:	**CONFIGURATION**
Run Number:	**A**
Scenario ID:	
Date: _____/_____/ 2009	**GO paired with ATC**

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

1. Rate your workload for **communications with ATC**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

2. How effective were **communications with ATC**?

1	2	3	4	5	6	7
Very ineffective			Moderately effective			Very effective

3. Rate your confidence level for the UAS transit during this scenario.

1	2	3	4	5	6	7
Very low			Moderate			Very high

4. Did you seek any information to aid you in your situational awareness (i.e., your timely knowledge of your environment and of what is happening as you perform your tasks during the scenario)?

YES / NO   If yes, please explain.

____
____
____
____
____

Post-Run Questionnaire – Pilot

Participant #:	**CONFIGURATION**
Run Number:	**B**
Scenario ID:	
Date: _____/_____/ 2009	**GO paired with UAS**

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

1. Rate your workload for **communications with ATC**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

2. How effective were **communications with ATC**.

1	2	3	4	5	6	7
Very ineffective			Moderately effective			Very effective

3. Rate your workload for **communications with the GO**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

4. How effective were **communications with the GO**.

1	2	3	4	5	6	7
Very ineffective			Moderately effective			Very effective

5. Rate your confidence level for the UAS transit during this scenario.

1	2	3	4	5	6	7
Very low			Moderate			Very high

6. Did you seek any information to aid you in your situational awareness (i.e., your timely knowledge of
your environment and of what is happening as you perform your tasks during the scenario)?
YES / NO If yes, please explain.

____

____

7. Were you comfortable making the decision to transit based on the information provided to you by the
GO? YES / NO Please explain.

____

____

Appendix D – SART Form

INSTRUCTIONS – All Participants (Post-Scenario)

Participant #:
Run Number:
Role: UAS PILOT GO ATC
Date: _____/_____/ 2009

Situational awareness is defined as "timely knowledge of your environment and of what is happening as you perform your tasks during the scenario."
Please consider the following definitions as you respond to the later questions:

Situational Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	Likeliness of situation to change suddenly.
Variability of Situation	Number of variables which require your attention
Complexity of Situation	Degree of complication (number of closely connected parts) of the situation
SUPPLY	
Arousal	Degree to which you are ready for activity; ability to anticipate and keep up with the flow of events
Spare Mental Capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation; degree to which you focused on important elements and events
Division of Attention	Ability to divide your attention among several key issues during the mission; ability to concern yourself with many aspects of current and future events simultaneously
UNDERSTANDING	
Information Quantity	Amount of knowledge received and understood
Information Quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

SART FORM – All Participants (Post-Run)

Rate your **overall workload**. That is, how much “effort” did this scenario require?

1	2	3	4	5	6	7
Very low			Moderate			Very high

Rate your **overall situational awareness**.

1	2	3	4	5	6	7
Very low			Moderate			Very high

Please rate the level of each component of situational awareness that you had *during the preceding scenario*. Circle the appropriate number for each component of situational awareness (e.g., complexity of situation).

DEMAND

Instability of situation: Low 1---------2---------3---------4---------5---------6---------7 High

Variability of situation: Low 1---------2---------3---------4---------5---------6---------7 High

Complexity of situation: Low 1---------2---------3---------4---------5---------6---------7 High

SUPPLY

Arousal: Low 1---------2---------3---------4---------5---------6---------7 High

Spare mental capacity: Low 1---------2---------3---------4---------5---------6---------7 High

Concentration: Low 1---------2---------3---------4---------5---------6---------7 High

Division of attention: Low 1---------2---------3---------4---------5---------6---------7 High

UNDERSTANDING

Information quantity: Low 1---------2---------3---------4---------5---------6---------7 High

Information quality: Low 1---------2---------3---------4---------5---------6---------7 High

Familiarity: Low 1---------2---------3---------4---------5---------6---------7 High

Appendix E - SME Observer Forms

ATC SME Observer Form

OTS observer name:
Observed Participant #:
Run #/Scenario #:
Date:
Scenario start time (clock time):

Motivation during run. Please check (√) only one.

☐ Positive (attentive and cooperative)
☐ Negative (alert but uncooperative)
☐ Apathetic (just getting it over with)

The participant:

☐ Yes	☐ No	Followed defined procedures
☐ Yes	☐ No	Used prescribed phraseology
☐ Yes	☐ No	Used correct communication pathway
☐ Yes	☐ No	Performed clear/concise communications
☐ Yes	☐ No	Performed required coordination
☐ Yes	☐ No	Maintained separation at all times
☐ Yes	☐ No	Issued proper clearances/approvals
☐ Yes	☐ No	Looked at the GO scope

Run Execution. Please check (√) all that apply.

☐ Run completed
☐ Run delayed
☐ Hardware malfunction
☐ Software malfunction
☐ Run Required repeat

Rate the **overall workload of the participant you observed** (i.e., how much “effort” did it require?)

1	2	3	4	5	6	7
Very low			Moderate			Very high

In your opinion, **rate the complexity** of the operation you observed.

1	2	3	4	5	6	7
Very low			Moderate			Very high

Comment on any other issues you observed that could aid the experiment team (use back if needed)

____

____

GO SME Observer Form

OTS observer name:
Observed Participant #:
Run #/Scenario #:
Date:
Scenario start time (clock time):

	****RECORD UAS PILOT transit request time (use simulation time)****
	****RECORD VERBALIZED TRANSIT DECISION TIME (use simulation time)****

Motivation during run. Please check (√) only one.

☐ Positive (attentive and cooperative)
☐ Negative (alert but uncooperative)
☐ Apathetic (just getting it over with)

The participant:

☐ Yes	☐ No	Followed defined procedures
☐ Yes	☐ No	Used prescribed phraseology
☐ Yes	☐ No	Used correct communication pathway
☐ Yes	☐ No	Performed clear/concise communications
☐ Yes	☐ No	Performed required coordination
☐ Yes	☐ No	Communicated/coordinated "transit approval" effectively

Run Execution. Please check (√) all that apply.

☐ Run completed
☐ Run delayed
☐ Run Required repeat

Red-Yellow-Green display/logic. Please check (√) all that apply.

☐ Worked as designed/expected
☐ Unrealistic performance

Rate the **overall workload of the participant you observed** (i.e., how much "effort" did it require?)

1	2	3	4	5	6	7
Very low			Moderate			Very high

In your opinion, **rate the complexity** of the operation you observed.

1	2	3	4	5	6	7
Very low			Moderate			Very high

Comment on any other issues you observed that could aid the experiment team (use back if needed).

____

____

UAS PILOT SME Observer Form

OTS observer name:
Observed Participant #:
Run #/Scenario #:
Date:
Scenario start time (clock time):

☐ Yes	☐ No	**UAS transitioned successfully**

Motivation during run. Please check (√) only one.

☐ Positive (attentive and cooperative)
☐ Negative (alert but uncooperative)
☐ Apathetic (just getting it over with)

The participant:

☐ Yes	☐ No	Followed defined procedures
☐ Yes	☐ No	Used prescribed phraseology
☐ Yes	☐ No	Used correct communication pathway
☐ Yes	☐ No	Performed clear/concise communications
☐ Yes	☐ No	Performed required coordination
☐ Yes	☐ No	Communicated Transition Intent effectively (Configuration B only)
☐ Yes	☐ No	Utilized the MPO display

Run Execution. Please check (√) all that apply.

☐ Run completed
☐ Run delayed
☐ Run Required repeat

UAS HILSIM. Please check (√) all that apply.

☐ Worked as designed/expected
☐ Unrealistic performance
☐ Displays flawless
☐ Displays malfunctioned (explain)
☐ Controls flawless
☐ Controls malfunctioned (explain)

Rate the **overall workload of the participant you observed** (i.e., how much "effort" did it require?)

1	2	3	4	5	6	7
Very low			Moderate			Very high

In your opinion, **rate the complexity** of the operation you observed.

1	2	3	4	5	6	7
Very low			Moderate			Very high

Comment on any other issues you observed that could aid the experiment team (**use back**).

Appendix F - Post-Experiment Questionnaires

Post-Experiment Questionnaire – Controller and GO

Participant #:___________

Instructions:
Please answer the following questions based upon your overall experience in the simulation. Your answers will remain anonymous.

1. Compared to your typical work environment, what effect, if any, did the **'WAK online workload rating'** have on your **performance**?

1	2	3	4	5	6	7
Negative effect			No effect			Positive effect

Explain how the 'WAK online workload rating' affected your **performance**, if at all.

____
____
____

2. Rate the **realism of the overall simulation environment.**

1	2	3	4	5	6	7
Very unrealistic						Very realistic

3. Rate the **realism of the simulation traffic.**

1	2	3	4	5	6	7
Very unrealistic						Very realistic

4. Describe anything that could be changed to improve the realism of the simulation.

____
____
____

5. Are there any additional tools, requirements or procedures (e.g., for communications, automation, surveillance) you feel are necessary to implement the proposed concept in an operational setting?

____
____
____
____

6. Describe any positive aspects of the 'Red-Yellow-Green light' concept.

____
____
____
____

7. Describe any negative aspects of 'Red-Yellow-Green light' concept.

____

8. For this operation, which configuration (GO paired with ATC, GO paired with UAS) did you prefer? Why?

____

9. Is there anything about the study that we should have asked or that you would like to comment about?

____

10. In your opinion, do you feel the GO position should be staffed by a controller? YES / NO Please explain.

____

11. When performing the GO role, rate your **awareness o**f the **'Red-Yellow-Green' Light indicator.**

1	2	3	4	5	6	7
No awareness			Moderately aware			Extremely aware

12. When performing the GO role, what effect, if any, did the **'Red-Yellow-Green' Light indicator** have on your **performance**?

1	2	3	4	5	6	7
Negative effect			No effect			Positive effect

13. Explain how the **'Red-Yellow-Green' Light indicator** affected your **performance**, if at all.

____

Post –Experiment Questionnaire – Pilot

Participant #:___________

Instructions:
Please answer the following questions based upon your overall experience in the simulation. Your answers will remain anonymous.

1. Compared to your typical work environment, what effect, if any, did the **'WAK online workload rating'** have on your **performance**?

1	2	3	4	5	6	7
Negative effect			No effect			Positive effect

Explain how the 'WAK online workload rating' affected your **performance**, if at all.

____

____

____

2. Rate the **realism of the overall simulation environment** compared to actual operations.

1	2	3	4	5	6	7
Very unrealistic						Very realistic

3. Describe anything that could be changed to improve the realism of the simulation.

____

____

____

4. Are there any additional tool, requirements or procedures (e.g., for communications, automation, surveillance) you feel are necessary to implement the 'Red-Yellow-Green light' concept in an operational setting?

____

____

____

____

____

5. Describe any positive aspects of the 'Red-Yellow-Green light' concept.

____

____

____

____

____

6. Describe any negative aspects of the 'Red-Yellow-Green light' concept.

7. Which configuration (receiving the transition approval from the GO or the ATC) did you prefer? Why?

8. Is there anything about the study that we should have asked or that you would like to comment about?

Appendix G – Simulation Pilot Observer Form

SIMULATION PILOT Observer Form

OTS observer name:
Observed Pilot:
Run #/Scenario #:
Date:
Scenario start time (clock time):

Motivation during run. Please check (√) only one.

☐ Positive (attentive and cooperative)
☐ Negative (alert but uncooperative)
☐ Apathetic (just getting it over with)

The Sim Pilot:

☐ Yes	☐ No	Followed defined procedures
☐ Yes	☐ No	Used prescribed phraseology
☐ Yes	☐ No	Used correct communication pathway
☐ Yes	☐ No	Performed clear/concise communications
☐ Yes	☐ No	Performed required coordination
☐ Yes	☐ No	Maintained separation at all times
☐ Yes	☐ No	Issued proper clearances/approvals

Run Execution. Please check (√) all that apply.

☐ Run completed
☐ Run delayed
☐ Hardware malfunction
☐ Software malfunction
☐ Run Required repeat

Rate the **overall workload of the pilots you observed** (i.e., how much "effort" did it require?)

1	2	3	4	5	6	7
Very low			Moderate			Very high

In your opinion, **rate the complexity** of the operation you observed.

1	2	3	4	5	6	7
Very low			Moderate			Very high

Comment on any other issues you observed that could aid the experiment team (use back if needed)

____
____
____

Appendix H – Verbal Instructions for Participants

Practice Scenario Instructions
During this brief practice scenario, please take the opportunity to familiarize yourself with your position. Familiarize yourself with the instruments and the Workload Assessment Keypads, or WAKs as we call them. This practice scenario is for your benefit and you should use this time to prepare for the scenarios that will follow. I will now read the WAK instructions to you.

Operations Instructions (Practice and Experiment)
During this scenario run, please control traffic, perform the GO role, or pilot the aircraft as you normally would with the addition of the new procedures as described in the operational briefing (reinforce procedures as necessary). Additionally, in every scenario, you will be making workload ratings using the WAK. I will now read the WAK instructions to you.

WAK Instructions
(The full set of instructions will be read at the beginning of each test day). An abbreviated set of instructions will be read prior to each experimental run. The abbreviated instructions will omit the first paragraph below.)

One purpose of this research is to obtain an accurate evaluation of workload. By workload, we mean all the physical and mental effort that you must exert to do your job. This includes maintaining the "picture," planning, coordinating, decision making, communicating, and whatever else is required to maintain a safe and expeditious traffic flow and flight. Workload is your perception of how hard you must work to perform all of the tasks necessary to meet these demands. Workload levels fluctuate. All pilots and controllers, no matter how proficient, will experience all levels of workload at one time or another. It does not detract from a pilot or controller's professionalism when he or she indicates that he or she is working very hard at certain times or that he or she is hardly working at other times.

Every two minutes the WAK device, located at your position, will emit a brief tone and the 10 buttons will illuminate. The buttons will remain lit for 20 seconds. Please tell us what your workload is at that moment by pushing one of the buttons numbered from 1 to 7.

Use the following as a scale when responding on the WAK:

Workload level	Description
7	No spare capacity in case of unexpected situations
5-6	Rather high work load, but still manageable
4	Normal
2-3	Starting to be boring
1	Too little to do to maintain focus

Feel free to use the entire rating scale and tell us honestly how hard you are working at the instant that you are prompted. Do not sacrifice the safe and expeditious flow of traffic in order to respond to the WAK device.

Does anyone have any questions? (After answering questions, if any, instruct participants to do comm check with pilots and adjacent sectors and centers.)

Appendix I – Supplemental Qualitative Data

End briefing notes:
This transcription is not verbatim, but summarizes specific elements of participants' verbal conversations during debrief sessions.

UAS PILOT: When given a two-alternative forced choice question, preferred configuration A.
Thought it would be best to blend both configurations. Suggested a configuration with some of the aspects of both configuration A and B. Only experienced with navigation, so not familiar with calling Approach.

ATC/GO: When given a two-alternative forced choice question, preferred configuration B.
Mainly because of the workload factors in configuration A being greater, however, both participants felt an ability to communicate with other operator was optimal.

Config. A	PROS	CONS
UAS PILOT:	Enhanced level of confidence, business as usual. Less effort, being told what to do (default state of experience). Less responsibility.	Not practiced in ATC communications in previous work. Not a certified pilot; relies on Mission Commander to execute all communications with ATC. Reported slight lag in simulator performance.
ATC/GO:	Real-time situations. View other scope (no clutter on main). Direct communication with other operator.	Tempted to look at GO scope, away from ATC scope. Pop-up situation had no procedure guidance in this simulation. (Note: this was intentional) Communications less accurate in this simulation, more realistic communications. More guidance for next layer of procedures.

Config. B	PROS	CONS
UAS PILOT:	May find good use in augmented environment. Received more detailed information. Confident in GBSAA operator's situational awareness for transition.	Did not feel adequate training/practice was provided for this configuration. Unclear about process. Checked in, often with no response. Expressed concerns about his vigilance. Confusion resulted from seeking the feedback of ATC transition approval.
ATC/GO:	During busy time benefit of known/observed traffic. Less workload.	Should always have communications between operators for direct coordination in NAS with potential conflicts and delay updates. Lengthy timeline for completing all tasks, which may have affected flow of traffic.

"Modified procedure" comments (All configuration A):

UAS PILOT:	Liked modified procedures; seemed smoother. Information was provided by ATC without prompting. Better look into future, with more communication and guidance.
ATC/GO:	More realistic. Would be safer for GO, but increased ATC workload. Frustrating at times. "Traffic update" area parameters imprecise.