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Air Traffic Control Feasibility Assessment of Small Aircraft Transportation System (SATS) Higher Volume Operations (HVO)

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Technical Report

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16. Abstract

The National Aeronautics and Space Administration's (NASA's) Small Aircraft Transportation System (SATS) Higher Volume Operations (HVO) research team collaborated with the Federal Aviation Administration's (FAA's) William J. Hughes Technical Center to provide a real-time simulation environment for conducting three proof of concept investigations of SATS HVO from an Air Traffic Control (ATC) perspective. The SATS HVO concept aims to enable simultaneous operations by multiple aircraft in airspace where non-radar procedures are applied, in and around small non-towered airports in near all-weather conditions. By allocating a Self-Controlled Area (SCA) in the airport's airspace wherein pilots assume separation responsibility, aircraft arrivals and departures are no longer limited by the current day 'one-in, one-out' operation in Instrument Meteorological Conditions (IMC). The main intent of the simulations was to collect data from Certified Professional Controllers (CPCs) on workload and feasibility of SATS HVO in the operational environment from terminal and en route views. CPCs provided feedback on SATS procedures, phraseology, and the display of SATS related information. The information obtained will assist NASA researchers in the continued development and refinement of the SATS HVO concept.

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The entire SATS HVO simulation team would like to thank the Certified Professional Controller (CPC) participants from the Philadelphia Terminal Radar Approach Control facility (PHL TRACON) and the Washington Air Route Traffic Control Center (ZDV ARTCC) for their enthusiastic participation and valuable feedback during the studies.

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Executive Summary

The objective of the National Aeronautics and Space Administration's (NASA's) Small Aircraft Transportation System (SATS) Higher Volume Operations (HVO) research endeavor is to enable simultaneous operations by multiple aircraft in airspace where non-radar procedures are applied in and around small non-towered airports in near all-weather conditions (Johnson, 2002). Today, there are minimal Air Traffic Control (ATC) services at these non-towered airports. The Visual Flight Rules (VFR) pilot that uses these airports uses the Common Traffic Advisory Frequency (CTAF) for announcing position and intentions. To ensure safe operations, current day Instrument Flight Rules (IFR) procedures limit arrivals and departures at these airports to one-in, one-out under instrument meteorological conditions (IMC).

The SATS HVO project is focused on providing proof of concept demonstrations of the benefits of SATS HVO from both flight deck and ATC perspectives, and collecting data adequate for Federal Aviation Administration (FAA) consideration, leading to further research and development of relevant operating capabilities and eventual application in the National Airspace System (NAS). As such, the concept emphasizes integration with the current and planned NAS with a design approach that is simple from both a procedural and system requirements standpoint.

The principle objective of the simulation efforts described in this report was to collect feedback on the viability of SATS HVO from an ATC perspective. This was the first opportunity Certified Professional Controllers (CPCs) had to experience SATS operations in a real-time simulation environment, provided by the FAA's William J. Hughes Technical Center laboratories. The main intent was to collect data from the CPCs on workload and the feasibility of SATS HVO. In addition, researchers collected data on other aspects of SATS HVO, including assessments of SATS procedures in the airspace surrounding two non-towered airports. The information obtained will assist NASA researchers in the continued development and refinement of the SATS HVO concept.

CPCs from Washington Air Route Traffic Control Center (ZDC ARTCC) and Philadelphia Terminal Radar Approach Control (PHL TRACON) participated in three independent simulations (referred to as Phases I, II, and III). The studies provided an initial look into the controller perspective on SATS HVO. The simulations included both current day, or baseline, and SATS HVO scenarios. The transition procedures, airspace development, phraseology, and other SATS specific details developed for the simulations were a first attempt at modeling the SATS concept for the ATC operational environment. The feedback collected from participating CPCs will assist in refining these essential components. Although quantitative data were analyzed, more emphasis was placed on the CPC subjective feedback for further development of the concept.

In all three simulations, SATS HVO did not affect controller workload as compared to baseline conditions. In other words, the new concept did not increase or decrease controller workload as compared to current day operations. Controller participants were able to handoff aircraft at an earlier time during the SATS scenarios and thereby reduce the number of aircraft within positive control. Transferring SATS aircraft to the Self-Controlled Area (SCA) also negated the need to deliver clearances to land for those aircraft. In addition, encompassing the missed approach pattern within the SCA eliminated ATC concern for missed approaches.

Most CPC participants viewed SATS HVO as favorable due to the transferring of responsibility from ATC to the flight crew once an aircraft entered the SCA. Controllers cited issues that need to be addressed, however, before the SATS HVO concept could be operationally feasible. These issues include the need to clearly define roles and responsibilities for ATC and pilots, refine clearance procedures and phraseology into and out of the SCA, and reduce or tailor the size of the SCA to the specific airspace for which it is sited. Future research of the SATS operational concept should also explore the mixed equipage issue. Participants in this study felt the issues surrounding the impact of mixed equipped aircraft would be significant.

1. Introduction

This document describes the test procedures and results for a joint Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) Small Aircraft Transportation System (SATS) Higher Volume Operations (HVO) research endeavor. Three small-scale simulations were conducted at the FAA William J. Hughes Technical Center (WJHTC) from October 18 through December 19, 2004. This document describes the scope and research objectives of these experiments, the procedures, scenarios, measures, data analysis techniques employed during the simulations, the subsequent results, key findings, and recommendations for next steps.

1.1 SATS HVO Concept Overview

The SATS HVO objective is to enable simultaneous operations by multiple aircraft in airspace where non-radar procedures are applied in and around small non-towered airports in near all-weather (Johnson, 2002). Today, there are minimal Air Traffic Control (ATC) services at these non-towered airports. The Visual Flight Rules (VFR) pilot that uses these airports uses the Common Traffic Advisory Frequency (CTAF) for announcing position and intentions. To ensure safe operations, current day Instrument Flight Rules (IFR) procedures limit arrivals and departures at these airports to one-in, one-out under instrument meteorological conditions (IMC).

As described in the SATS HVO Operational Concept: Nominal Operations document (Abbott, Jones, Consiglio, Williams, & Adams, 2004), the general philosophy underlying the SATS HVO concept is "the establishment of a newly defined area of flight operations called a Self Controlled Area (SCA)". During periods of IMC, a block of airspace would be established around SATS designated non-towered, non-radar airports. Aircraft flying en route to a SATS airport would be on a standard IFR flight plan with ATC providing separation services. Within the SCA, pilots would take responsibility for separation assurance between their aircraft and other similarly equipped aircraft. Using onboard equipment and procedures, they would then approach and land at the airport. With SATS HVO, multiple aircraft could enter the non-controlled airport's airspace and land, rather than ATC being restricted to allowing one aircraft in at a time. Departures would be handled in a similar fashion. Transition procedures for aircraft entering and departing the SCA were the focus of investigation in the simulations described in this report.

A key component of the SATS HVO concept demonstration is a ground-based automation system, called an Airport Management Module (AMM) that provides sequencing information to pilots within the SCA (Abbott et al., 2004). The AMM is located at the demonstration airport and makes sequencing assignments based on calculations considering aircraft performance, position information, winds, missed approach requirements, and a set of predetermined operating rules for the SCA.

From the flight deck side, SATS HVO concept requires that aircraft have accurate position data (e.g., GPS-equipped), display information (e.g., Multi-Function Display), conflict detection and alerting avionics software, and be capable of transmitting and receiving data (e.g., ADS-B, data link).

The SATS HVO project is focused on providing a compelling proof of concept demonstration and data adequate for FAA consideration, leading to further research and development of relevant operating capabilities and eventual application in the National Airspace System (NAS). As such, the concept emphasizes integration with the current and planned NAS with a design approach that is simple from both a procedural and system requirements standpoint (Abbott et al., 2004).

1.2 Simulation Objectives

The principle objective of all three joint FAA/NASA experiments was to collect feedback on the viability of SATS HVO from an ATC perspective, with specific focus on air traffic control procedures and subsequent workload associated with transitioning aircraft in and out of the SCA. This was the first opportunity Certified Professional Controllers (CPCs) had to experience SATS operations in a real-time simulation environment. The main intent was to collect data from the CPCs on workload and feasibility of SATS HVO. In addition, researchers collected data on other aspects of SATS HVO, including assessments of SATS procedures and phraseology, in the airspace surrounding two non-towered airports. The information obtained will assist NASA researchers in the continued development and refinement of the SATS HVO concept.

1.3 Simulation Overviews

The three simulations will be referred to as Phases I, II, and III throughout this report, and they are briefly described in Sections 1.3.1 – 1.3.3. The methods, experimental designs, and data analysis techniques were the same for all three phases. The differences between the phases were the type of facilities investigated (i.e., terminal versus en route), and the types of laboratories involved. Four CPCs participated in each of the studies, resulting in feedback from a total of 12 CPC participants; 4 from a terminal facility and 8 from an en route facility.

1.3.1 Phase I: Terminal Sector

To provide a terminal perspective of the SATS HVO concept, Phase I simulated the North Arrival sector surrounding the Coatesville/Chester County Airport (40N), which is located in the western end of the Philadelphia Terminal Radar Approach Control (PHL TRACON) facility's airspace. As such, PHL CPCs were recruited as participants. Global Positioning System (GPS) approaches are currently in use at 40N and, therefore, were assumed in use during the simulation.

1.3.2 Phase II: En Route Sector

To provide an en route perspective of the SATS HVO concept, Phase II simulated Sector 22 surrounding the Danville Regional Airport (DAN), which is located in Washington (ZDC) Air Route Traffic Control Center's (ARTCC's) airspace. ZDC CPCs were recruited as participants.

1.3.3 Phase III: En Route Sector - Linked Simulation

The Phase III simulation repeated the same conditions as Phase II with the exception that in Phase III, the WJHTC linked in real-time to the NASA LaRC's Air Traffic Operations Laboratory (ATOL) (see Section 2.2.4) to provide a greater degree of realism to the study. In Phase III, instrument rated pilots, trained in SATS HVO procedures and communications, flew

SATS aircraft simulators in the LaRC ATOL. The LaRC ATOL pilots had a tailored SATS HVO multi-function display interface as well as out-the-window visuals and aircraft controls more akin to cockpit simulator capabilities than desktop simulator capabilities. ZDC CPCs were recruited as participants on the air traffic control side.

2. Method

2.1 Participants

2.1.1 Certified Professional Controllers

Controller participation in this study was strictly voluntary, and the privacy of all participants was protected. No individual names or identities were recorded or released in any reports. Each participant was assigned a participant code to apply to data collection forms. Strict adherence to all federal, union, and ethical guidelines was maintained throughout the study. During the initial briefing session, participants completed Consent Forms (see Appendix A) to participate, which stated the above assurances.

2.1.1.1 Philadelphia TRACON Controllers

Four CPCs from PHL participated in Phase I. Each CPC participated for two days of simulation. Only the North Arrival radar position was manned in this phase.

2.1.1.2 Washington ARTCC Controllers

A total of eight CPCs from ZDC participated in Phases II and III (four in each). Each CPC participated for two days of simulation. Only the Sector 22 radar position was manned in these phases. No Data controller positions (D-side) were simulated.

2.1.2 Simulation Pilots

2.1.2.1 WJHTC Pilots

Six trained WJHTC simulation pilots participated in each of the SATS simulation phases, one per workstation. In Phases I and II, during scenarios with SATS operations in effect, four of these pilots worked aircraft within SCA, and two controlled aircraft within the controlled airspace. During baseline (non-SATS) scenarios, all managed traffic was distributed among all six pilots. The pilots controlled Target Generation Facility (TGF)-generated aircraft targets (see Section 2.2.1) via computer workstations, and emulated pilot communications and actions and responded to ATC instructions. They also initiated pre-scripted air-to-ground communications as required. Simulation pilots were not subjects for study or evaluation.

2.1.2.2 NASA LaRC Pilots

In Phase III, NASA LaRC pilots flew the SATS aircraft, and the WJHTC simulation pilots operated all other simulated traffic.

2.2 Test Facility and Equipment

2.2.1 WJHTC Target Generation Facility

The TGF provided the ATC environment at the WJHTC, including the simulated radar sensors, airspace configuration, aircraft targets, and aircraft performance characteristics. The digital radar messages for targets were adapted to mimic actual NAS characteristics by including the radar and environmental characteristics of the simulated airspace. Simulated primary and beacon radar data was generated for each target and processed in a manner similar to normal radar data. Flight datablocks contained flight identification, beacon code, and altitude information. Target positions were automatically updated at the same rate experienced as in the field. The TGF also provided complete data recording and reduction capabilities that supported post-simulation analyses.

2.2.2 WJHTC Simulation Display Laboratory

CPC participants monitored and controlled traffic in the WJHTC Simulation Display Laboratory (SDL) during the test. They were stationed at one high resolution 20 x 20-inch Sony display, with two-way communications with the WJHTC and NASA LaRC simulation pilots.

2.2.3 WJHTC Simulation Pilot Laboratory

WJHTC simulation pilots operated TGF-generated aircraft targets from the Simulation Pilot Laboratory via Simulation-Pilot Workstations (SPW). The SPWs allowed the simulation pilots to alter aircraft flight parameters (e.g., altitude, routing, rate of climb) by entering commands into their specialized computers.

2.2.4 NASA LaRC Air Traffic Operations Laboratory

For Phase III, NASA LaRC's ATOL was linked in real time via T1 line to the WJHTC simulation test bed. The ATOL is a distributed desktop simulation environment that has hosted multi-piloted SATS HVO research studies for NASA. In the SATS simulation, the ATOL provided a realistic environment for pilots to fly SATS approaches to DAN.

2.3 Airspace

2.3.1 Philadelphia (PHL) TRACON North Arrival Sector - Coatesville/Chester County Airport

The SATS airport selected for the Phase I terminal sector study, 40N, is located within the lateral confines of PHL airspace, specifically, underlying the North Arrival sector, which owns the surface to 8,000 ft Mean Sea Level (MSL) over most of the sector. The exception to this is the holding pattern at BUNTS where the North Arrival sector owns from the surface to 6,000 ft.

The North Arrival sector configuration was applied to the Phase I simulation. Sector airspace video maps currently used for the North Arrival sector were displayed on the controller consoles. Additional information on the maps included the airport runway, GPS approach, departure fixes, and the SCA boundary.

A generic representation of the SCA airspace, with a 15 nm radius, was positioned in this sector during the SATS scenarios. The SCA was displayed during SATS scenarios only. For this simulation, all aircraft entering the SCA were assumed to be SATS-equipped. SATS arrivals flew to one of two Initial Approach Fixes (IAFs), COVBA or DOVPY, contained within the SCA on the GPS Runway 11 approach. Aircraft entering vertically (i.e., above the SCA) entered the SCA at 4,000 ft. Within the SCA, each IAF accommodated aircraft holding at 3,000 ft and 4,000 ft. Aircraft held at COVBA or DOVPY above 4,000 ft remained under positive control. Figure 1 contains a graphical depiction of the Coatesville/Chester County Airport/SCA in North Arrival sector airspace as simulated in the Phase I simulation.

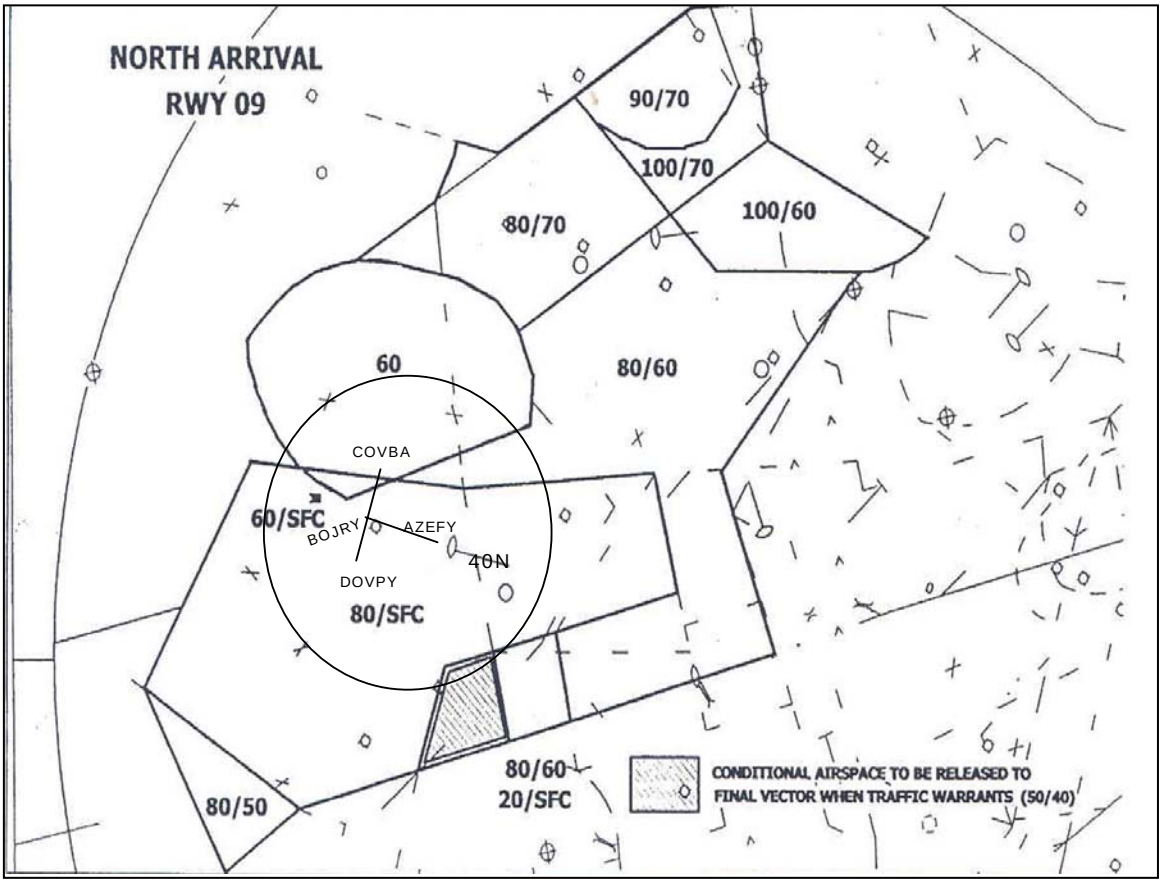

Figure 1. Coatesville/Chester County Airport - within PHL's North Arrival sector.

2.3.2 Washington ARTCC Sector 22 - Danville Airport

The SATS airport selected for the Phase II and III en route sector studies, Danville Regional Airport, is located within the lateral confines of ZDC, specifically, underlying Sector 22, a low altitude sector which owns from the surface to flight level 23000.

The Sector 22 configuration was applied to the Phase II and III simulations. Sector airspace video maps currently used for Sector 22 operations were displayed on the controller consoles. Additional information on the maps included the airport runway, GPS approach, departure fixes, and the SCA boundary.

For the simulations, a generic representation of the SCA airspace, with a 14.5 nm radius, was positioned in this sector during the SATS scenarios. The SCA was displayed during SATS scenarios only. For these simulations, all aircraft entering the SCA were assumed to be SATS-equipped. SATS arrivals flew to one of two IAFs, CATHY or ANNIE, contained within the SCA on the GPS Runway 20 approach. Aircraft entering vertically entered the SCA at 4,000 ft. Within the SCA, each IAF accommodated aircraft holding at 3,000 ft and 4,000 ft. Any aircraft held at CATHY or ANNIE at or above 4,000 ft remained under positive control. Figure 2 contains a graphical depiction of the Sector 22 airspace simulated in the Danville Regional Airport simulation.

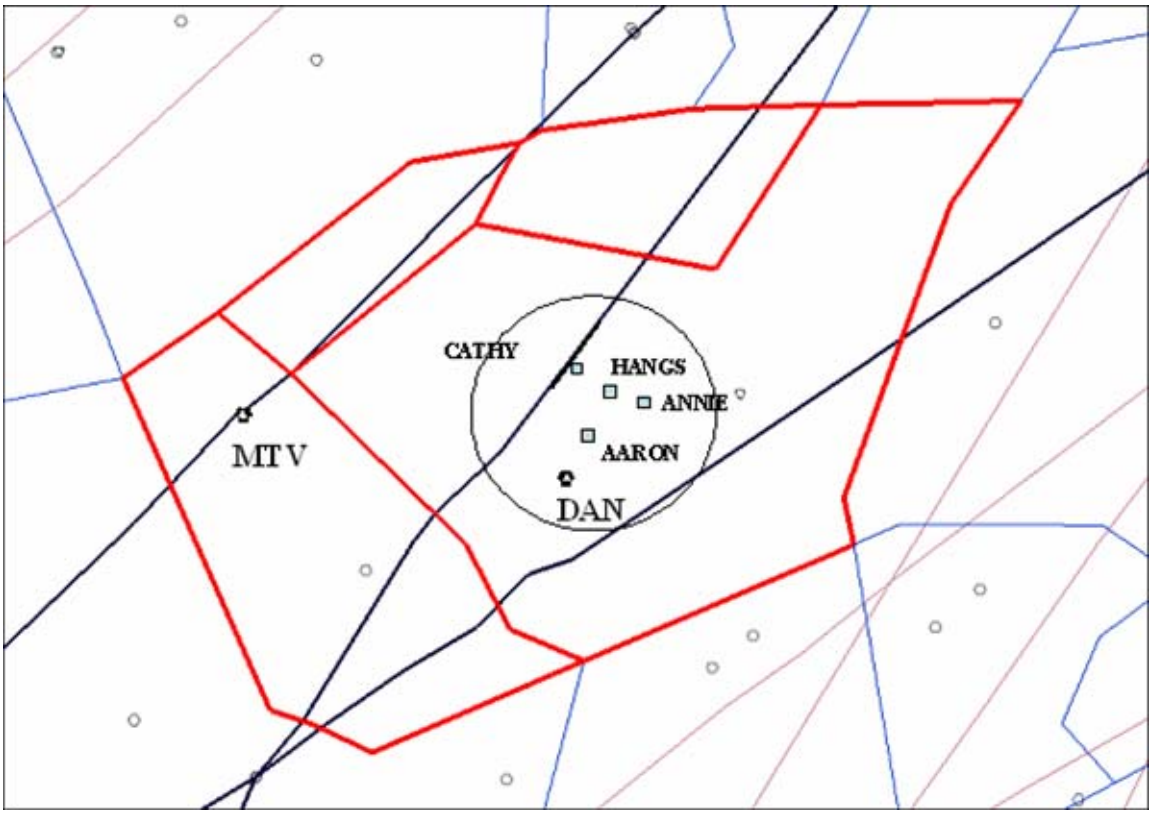

Figure 2. Danville Regional Airport - within ZDC Sector 22 airspace.

2.4 Traffic Scenarios

The researchers developed four traffic scenarios for all three simulations. Subject matter expert (SME) controllers from both PHL and ZDC assisted in the development and validation of the scenarios, which varied on two dimensions: traffic level and airspace environment. Traffic levels represented either current day traffic levels (augmented somewhat to ensure the CPC maintained a moderate level of activity) or future traffic levels, estimated for the year 2010. Traffic levels between today and future scenarios varied only by number of overflights, which were significantly more in the future scenarios. To be able to compare data, the number of arrivals and departures remained the same for all scenarios. Scenarios also varied by airspace environment, specifically, whether SATS operations were in effect or not. When SATS

operations were not in effect, the scenarios were considered baseline cases, representative of current day IMC operations at non-towered airports (i.e., one-in, one-out operation). Baseline arrivals and departures were ATC managed, whereas in SATS scenarios, SATS arrivals and departures were flight crew and/or simulation pilot managed. Table 1 describes the four traffic scenarios.

Table 1. Traffic Scenario Descriptions

Scenarios	Baseline Scenarios	SATS HVO Scenarios
Air traffic controller load was modeled to represent today's sector demand. *(Some additional traffic to/from the airports was simulated to ensure adequate complexity during the scenario).*	**Today Baseline (TB)** **Non-SATS**	**Today SATS (TS)**
Air traffic controller load was modeled to represent a future sector demand	**Future Baseline (FB)** **Non-SATS**	**Future SATS (FS)**

SATS scenarios varied somewhat in length (the scenarios ended when the last SATS arrival landed), but were approximately 45 minutes in length. Baseline scenarios ended after 55 minutes to ensure that there would be an adequate amount of comparable scenario time with the SATS scenarios. In the baseline scenarios, not all arrival traffic landed within the 55 minute timeframe. All scenarios began with overall sector traffic and one arrival aircraft 15 miles from the airport. Subsequent arrival traffic initialized outside the simulated airspace and arrived within a specified time of each other to simulate a "full" SCA in the SATS scenarios or normal holding situations in the baseline scenarios.

Weather conditions were IMC for all scenarios, requiring IFR operations to each airport. Only normal traffic and HVO operations were emulated; no off-nominal situations were included in this study.

One missed approach operation was conducted per scenario. Each missed approach was contained within the SCA, did not require pilot to ATC communication, and did not encroach on surrounding positive control airspace.

2.4.1 Today Baseline (Non-SATS)

The goal of the *today baseline* (TB) scenario was to evaluate the controller workload and other measures associated with IFR operations to/from the airports in today's environment, using today's ATC procedures of one operation into the non-controlled airport at a time. As in the current environment, all traffic was ATC managed in the TB scenario.

The TB scenario contained 7 arrivals, 1 departure, and overflight traffic. In the PHL simulation, the TB scenario contained approximately 90 overflight aircraft. In the ZDC simulations, the TB

scenario contained approximately 51 overflight aircraft. One missed approach was scripted to occur during the TB scenario. The scenario ended after 55 minutes regardless of how many arrivals touched down.

2.4.2 Today SATS

The goal of the *today SATS* (TS) scenario was to evaluate controller workload and other measures associated with SATS IFR operations to/from the airports in today's environment, using proposed SATS procedures.

The TS scenario contained the same traffic as the TB scenario. The TS scenario differed from the TB scenario in that all arriving and departing aircraft were assumed to be SATS-equipped. Therefore, arrivals into the airport were flight crew managed once the pilot received approval to enter the SCA (see Section 2.6 for procedural details). The scenario ended after all SATS arrivals touched down (approximately 45 minutes).

2.4.3 Future Baseline (Non-SATS)

The goal of the *future baseline* (FB) scenario was to evaluate the controller workload and other measures associated with IFR operations to/from the airports in a future environment, using today's ATC procedures of one operation into the non-controlled airport at a time. As in the current environment, all traffic was ATC managed in the FB scenario.

The FB scenario contained 7 arrivals, 1 departure, and overflight traffic. In the PHL simulation, the FB scenario contained approximately 108 overflight aircraft. In the ZDC simulations, the FB scenario contained approximately 59 overflight aircraft. Similar to the TB condition, one missed approach was scripted to occur during the FB scenario. As in the TB condition, the scenario ended after 55 minutes regardless of how many arrivals touched down.

2.4.4 Future SATS

The goal of the *future SATS* (FS) scenario was to evaluate controller workload and other measures associated with SATS IFR operations to/from DAN airport in a future environment (~ year 2010), using proposed SATS procedures.

The FS scenario contained the same traffic levels as the FB scenario. The FS scenario differed from the FB scenario in that all arriving and departing aircraft were assumed to be SATS-equipped. Therefore, arrivals into the airport were flight crew managed once the pilot received approval to enter the SCA (see Section 2.6 for procedural details). The scenario ended after all SATS arrivals touched down (approximately 45 minutes).

2.5 Experimental Design

The experimental design was a 2 x 2, within-subjects design. The two independent variables were traffic level (current and future) and airspace environment (non-SATS and SATS). Based on the sample of 4 CPCs per simulation, Table 2 depicts the order of test scenarios that were experienced by each participant. Each test scenario preceded and followed every other test scenario across subjects and was presented an equal number of times.

Table 2. Test Scenario Presentation per Subject

		Test Run			
	Test Participant	**1**	**2**	**3**	**4**
Phase I	PHL 1	TB	TS	FS	FB
	PHL 2	TS	FB	TB	FS
	PHL 3	FB	FS	TS	TB
	PHL 4	FS	TB	FB	TS
Phase II	ZDC 1	TB	TS	FS	FB
	ZDC 2	TS	FB	TB	FS
	ZDC 3	FB	FS	TS	TB
	ZDC 4	FS	TB	FB	TS
Phase III	ZDC 5	TB	TS	FS	FB
	ZDC 6	TS	FB	TB	FS
	ZDC 7	FB	FS	TS	TB
	ZDC 8	FS	TB	FB	TS

2.6 Procedure

Sections 2.6.1 through 2.6.5 describe the daily schedule of events, controller training and familiarization, controller procedures, and simulation pilot training and procedures for the three simulations.

2.6.1 Daily Schedule of Events

Each CPC participated in the SATS HVO simulations for approximately 1½ days. During that time, the CPCs completed training, four data runs (corresponding to the four traffic scenarios), debriefs, and questionnaires. Table 3 shows the daily schedule of events.

Table 3. Daily Schedule of Events

First Day		Second Day	
Time	**Event**	**Time**	**Event**
Hour 1	Controller Briefing and Familiarization training	Hour 1	Run 3 Post Scenario Questionnaires Debriefing
Hour 2		Hour 2	
Hour 3	Break Run 1 Post Scenario Questionnaires	Hour 3	Run 4
Hour 4		Hour 4	Final Debriefing and Questionnaires
Hour 5	Lunch	Hour 5	Travel
Hour 6	Run 2	Hour 6	
Hour 7	Post Scenario Questionnaires	Hour 7	
Hour 8	Debriefing	Hour 8	

2.6.2 Controller Training

Each CPC received a briefing on the objectives of the simulation prior to participating in the study. He/she learned about the SATS HVO concept, the impact it has on current procedures, and the roles and responsibilities associated with his/her participation (due to the length/size of the briefing, it is not included in this document). Each CPC also received hands-on familiarization training by performing a practice run on position with SATS operations in effect and with simulation pilots.

2.6.3 Controller Procedures

When SATS operations were in effect, controller procedures, including roles and responsibilities and phraseology, were affected. Sections 2.6.3.1 and 2.6.3.2 discuss the controller procedures implemented during the simulation.

2.6.3.1 Responsibility

For baseline scenarios, CPC participants were instructed to work traffic as they do in their current environment. In other words, when SATS operations were NOT in effect, controllers used the one-in, one-out arrival procedure. Aircraft not cleared for the approach were stacked in holding, or in some cases given delay vectors.

In SATS scenarios, multiple aircraft could make approaches to the airport simultaneously. Once an aircraft received approval and entered the SCA, the CPCs were no longer responsible for that aircraft.

Outside SCA. The CPC was responsible for all aircraft outside the SCA, whether they were SATS-equipped or not. CPCs applied normal current day ATC procedures. Inside the SCA, no ATC services were provided and therefore, pilots were responsible for their own separation. If

the SCA capacity was reached, the pilots received a "standby" message from the AMM upon requesting a landing sequence. The CPC was made aware of such a situation when either 1) a pilot informed him/her of a standby to enter the SCA, or 2) the CPC asked a pilot of his/her SCA entry status. CPCs were instructed to issue holding instructions when this type of action became necessary.

Transitioning into SCA - SATS Arrivals. As SATS-equipped aircraft approached the SCA with intent to enter, pilots were required to inform controllers when they received sequence information from the AMM to enter the SCA. Once the pilot informed the CPC that he/she had AMM approval to enter the SCA, the controller issued a "descend at pilot's discretion, report entering the SCA." When the pilot reported entering the SCA, the controller advised the pilot to change to advisory frequency," and then terminated radar service. At this point, the CPC no longer had responsibility for that aircraft. The SATS aircraft could enter either vertically or laterally into the SCA according to their AMM assigned arrival sequence. SATS aircraft first arriving to an IAF were given AMM approval that allowed them to request immediate descents from the CPCs and to enter laterally through the side of the SCA. When multiple SATS aircraft were arriving at the IAFs, they had to enter vertically and received their AMM sequence at the hold above the IAF (5,000 ft) once an SCA space was open to enter.

Transitioning out of SCA - SATS Departures. SATS-equipped aircraft waiting to depart the non-controlled airport during SATS operations were required to request a release from the CPC to depart. Once the CPC acknowledged and granted a departure release, he/she expected that aircraft to exit the SCA into his/her controlled airspace sometime thereafter (the controller could have issued a "void clearance" time). Other than issuing the release, the CPC had no responsibility for the aircraft while it was inside the SCA.

2.6.3.2 Phraseology and Procedures

The implementation of an SCA into the airspace system would represent a fundamental change in the roles and responsibilities of pilots and controllers. In order to address aspects of the SATS concept that do not exist in today's environment, new procedures and phraseology were developed for this simulation. The proposed procedures and communications (see Appendix B for sample phraseology) were intended to address the changes in these tasks. To the extent possible, phraseologies and procedures currently used in the NAS were used.

2.6.4 Simulation Pilot Training

WJHTC simulation pilots were trained on SATS procedures for the simulation. Their training consisted of flying aircraft and responding to controller SME commands in actual traffic scenario dry runs for several weeks prior to the actual simulation. The extent of the training ensured a realistic representation of SATS operations and accordance to SATS procedures within the SCA during the test. It is important to again note, however, that simulation pilot performance was not evaluated in this study. The focus of the test was on ATC and primarily the airspace outside of the SCA.

Simulation pilots participating at NASA LaRC in Phase III were instrument rated pilots and also trained prior to their participation on SATS procedures and phraseology. Again, pilot performance was not evaluated.

2.6.5 Simulation Pilot Procedures

For Phases I and II, one simulation pilot operated sector traffic and handled all flights normally. If a SATS aircraft (indicated by the airport arrival in the flight plan) initiated in the simulated sector, it was immediately handed off to a designated WJHTC workstation for SCA bound aircraft. For Phase III, WJHTC simulation pilots operated all study sector traffic, and the NASA LaRC pilots flew all SATS arrival aircraft.

The TGF system designated the SCA as a "sector" for logistical purposes. At a pre-determined distance from the SCA, each SATS aircraft executed an automated command requesting entrance into the SCA. The pilot then received a prompt modeling the AMM's reply. The AMM message contained information the pilot needed to make the approach, for example, which IAF was assigned, and where to go in the event of a missed approach. The pilot was instructed to immediately report this reply (whether entry approved or standby) to the controller.

If the AMM approved entry, the pilot informed the controller that he/she had approval for the SCA and the IAF requested. The controller then issued a descent at pilot's discretion, change to CTAF instruction, and then termination of radar services. Aircraft granted lateral entries by the AMM could enter through the side of the SCA by requesting descent, flying to the IAF, and then beginning the approach. Aircraft not granted entries by the AMM were instructed to go to the requested IAF and hold at the altitude directed by the controller. If an aircraft was already at the IAF, the pilot was required to wait until that aircraft had left its altitude before descending further, and maintain 1,000 ft separation. Once the aircraft reached 5,000 ft, and space was available within the SCA, the AMM granted a vertical entry and the pilot was instructed to follow his/her sequence to the airport while maintaining separation.

If the AMM issued a "stand-by" reply, the pilot informed the controller and followed the controller's instructions. Upon receiving an approval to enter the SCA, the pilot informed the controller immediately, and conducted operations accordingly.

Pilots performed missed approaches by manually turning the aircraft right or left 90 degrees and proceeding to the appropriate fix.

Departures were conducted as in today's environment. The pilot called the controller on the appropriate sector frequency and requested a release. When given clearance, the pilot was free to take-off when the runway was available. The pilot reported "rolling" and informed the controller that he or she was exiting the SCA.

2.7 Simulation Assumptions and Limitations

The three simulations reported in this document were the first of their kind to include CPCs as participants. The scenarios were designed to provide controllers with an opportunity to learn about SATS HVO and experience controlling traffic in a simulated SATS environment. The researchers referred to the simulations as 'proof of concept' studies, wherein they would collect

initial feedback from CPC participants on the SATS HVO concept. This feedback would then highlight areas/issues requiring further research and/or development, specifically related to the ATC component of SATS HVO.

When interpreting test results, the reader should be aware of the following assumptions that were made about SATS HVO for these studies:

- Pure SATS environment existed within SCA (i.e., all aircraft were SATS equipped and self-separating),
- SCAs at both airports were generic (i.e., dimensions were a 15nm circle from the final approach fix for both airports).
- Controller had NO responsibility for aircraft after the point at which the aircraft entered the SCA,
- One sector of airspace was simulated, therefore no 'between-sector' coordination was simulated (i.e., no point-outs, controllers were instructed to take all incoming hand-offs, no adjustments to the flow of traffic from adjacent sector could be requested),
- No off-nominal events (i.e., equipment failure), were simulated, and
- Missed approaches were completely contained within the SCA and were assumed to have no impact on positive controlled airspace.

In addition, the reader should take into account that each simulation had a rather small sample size (i.e., 4 participants). Further research would be necessary to provide data on SATS HVO feasibility outside the scope of these assumptions and limitations.

3. Data Analysis

Data collection consisted of routine forms intended to gather information on controller background experience, as well as a range of qualitative and quantitative data. Since the main focus of the study was on controller subjective feedback, a great deal of questionnaire ratings and open-ended responses were collected and analyzed. To supplement that data, the researchers collected several system performance measures related to communications and arrival rates. All of these data collection measures and subsequent analyses are presented in the following sections.

3.1 Background Experience

CPC participants completed Background Questionnaires (see Appendix C) at the beginning of the simulation to provide the researchers with demographic information and depth of controller experience. Summary background experience is shown in Table 4.

Table 4. CPC Background Experience

	Mean Age (years)	Total Controller Experience (years)	Experience in Terminal or En Route Environment (years)	Experience at Current Facility (years)
PHL – Phase I	39.8	16.8	10.8	8.7
ZDC – Phase II	44	22.5	19.7	18.2
ZDC – Phase III	37.8	16.9	11.4	11.4

3.2 Qualitative Feedback

Research personnel collected qualitative, or subjective, data from participants using online workload assessment techniques, questionnaires, and debriefing sessions. Table 5 summarizes the qualitative data collection method objectives and their frequency of use. The data collected included workload and situation awareness assessments, and written and verbal responses pertaining to the SATS concept and issues associated with its implementation. Unless otherwise noted, all applicable analysis was conducted with an alpha level of .05.

Table 5. Subjective Data Collection Methods

Instrument	**Frequency**	**Objective**	**More Information**
Workload Assessment Keyboard	Five-minute intervals	Gather data on controller perceived workload over the course of each traffic scenario	Section 3.2.1
Post-Scenario Questionnaire	Every run	Collect situation awareness ratings Collect assessment of workload, procedures/phraseology, and difficulty of scenario	Appendix D
Post-Simulation Questionnaire	Once	Collect rating and open-ended data on simulation-specific issues, including ▪ SATS HVO concept ▪ Transition procedures/phraseology ▪ Workload ▪ Simulation realism	Appendix E
Post-Simulation Debriefing	Once	Allow for open discussion of additional issues of interest to CPC	N/A Verbal discussions

3.2.1 Workload

On Post-Simulation Questionnaires, controllers provided ratings of the overall effects of SATS HVO on workload as compared to today's conventional non-radar procedures. Table 6 shows the results by simulation. CPCs in all three simulations generally reported a decrease in workload due to SATS operations (i.e., mean values < 4). The Phase II ZDC participants

showed the greatest range in opinion on this issue. Nevertheless, they leaned towards a decrease in workload with SATS HVO.

Table 6. Mean Ratings on SATS HVO Workload

	Phase I		**Phase II**		**Phase III**	
Workload	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***
Effect of SATS on workload compared to current day operations **Greatly Decreased ① ② ③ ④ ⑤ ⑥ ⑦ Greatly Increased**	2.3	.50	3.3	2.1	1.8	1.0

Controllers also provided workload assessments during test scenarios and following their participation in the simulations in the form of open-ended written and verbal feedback. During the traffic scenarios, CPCs provided real-time ratings of workload using electronic keypads [i.e., Workload Assessment Keyboards (WAKs)]. The keypads contained number scales from 1 to 7 that automatically illuminated and sounded tones at 5-minute intervals, prompting the participants to select a rating that corresponded to their workload level at that moment in time. A rating of 1 corresponded to the lowest workload rating and 7 corresponded to the highest workload rating. If the participant did not enter a rating within 20 seconds of the prompt, the keypad lights extinguished and a rating of "99" was automatically entered. Sections 3.2.1.1 through 3.2.1.3 present more details of the during-the-run workload assessments by simulation phase.

3.2.1.1 Phase I - PHL

During-the Run Workload. The mean workload ratings were fairly low for the baseline scenarios (TB = 1.78, TS = 1.39), and in the moderate range for future traffic scenarios (FB = 4.26, FS = 3.03). Researchers performed a two-tailed Wilcoxon signed ranks test, which is a nonparametric version of the related samples t-test for ranked scores, to determine if workload varied significantly between baseline and SATS scenarios within the same traffic level[1]. A comparison of TB with TS showed no significant differences in controller workload for Phase I. A comparison of FB with FS also showed no significant differences in controller workload. Although not statistically significant, controller workload was slightly less during SATS runs in both the today and future environment (see Figure 3).

Overall Workload. Phase I controllers reported a general reduction in workload with SATS HVO in effect largely due to the fact that they had no responsibility for the aircraft upon entering the SCA. However, they commented that transferring separation responsibility is a change to the current controller philosophy. In addition, the issue of who is responsible for approval into SCA needs to be made clear.

[1] The analyses of interest were those comparing Baseline and SATS scenarios to identify the impacts of SATS operations. Researchers anticipated workload to increase somewhat between today and future traffic levels, and therefore did not perform any statistical comparisons of these factors.

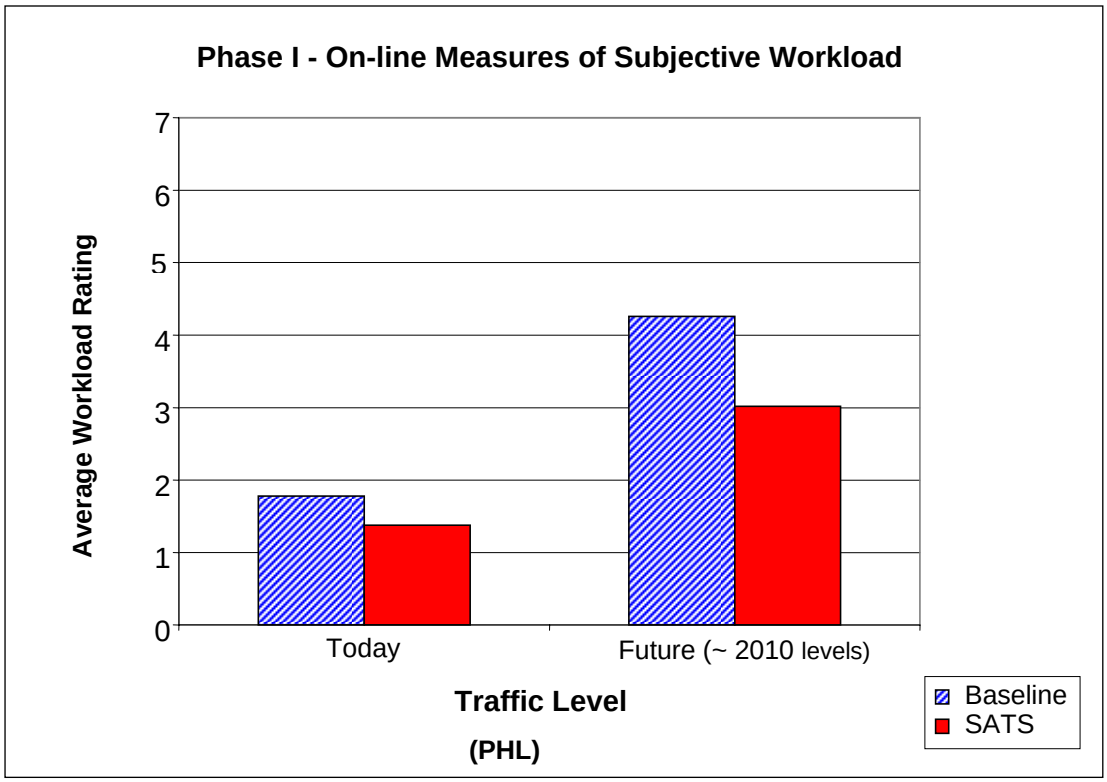

Figure 3. Phase I mean workload ratings for baseline and SATS scenarios.

3.2.1.2 Phase II - ZDC

During-the Run Workload. The mean workload ratings were more in the moderate range for the Phase II ZDC controllers as compared to the Phase I PHL CPCs. The baseline scenario workload ratings were lower (TB = 3.93, TS = 3.34) than the future scenario ratings (FB = 5.21, FS = 5.68), as expected. Researchers performed a Wilcoxon signed ranks test to determine if workload varied significantly between baseline and SATS scenarios. A comparison of TB with TS showed no significant differences in controller workload (see Figure 4). A comparison of FB with FS also showed no significant differences in controller workload.

Overall Workload. Phase II controllers commented that the SATS HVO operational procedures took the decision-making of sequencing away from the controller and eliminated a lot of time-consuming radio transmissions. Controllers reported a decrease in workload by not having to issue aircraft arrival clearances, but conversely, reported an increase in workload by having more aircraft on frequency. One controller stated that clearing aircraft into the SATS airspace was very easy.

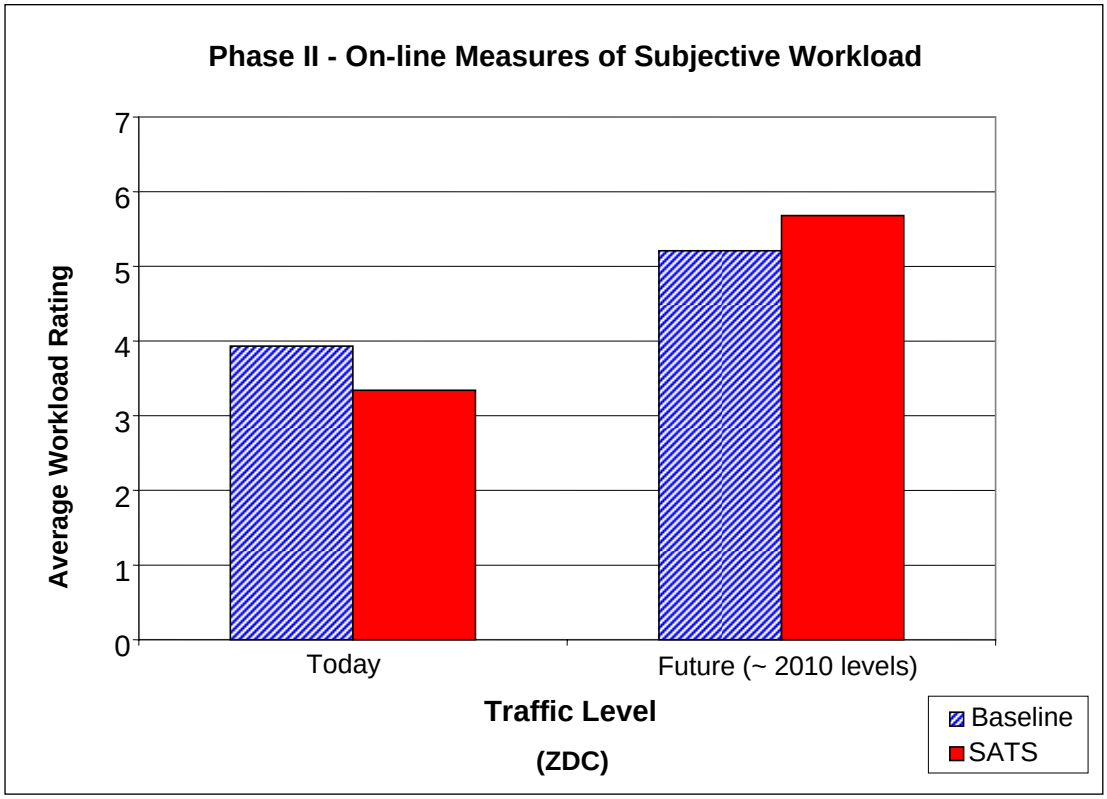

Figure 4. Phase II mean workload ratings for baseline and SATS scenarios.

3.2.1.3 Phase III – ZDC (Linked)

During-the Run Workload. The mean workload ratings were in the moderate range for the Phase III ZDC controllers, with the baseline ratings being lower (TB = 3.22, TS = 2.66) than the future ratings (FB = 4.13, FS = 4.63). Researchers performed a two-tailed Wilcoxon signed ranks test to determine if workload varied significantly between baseline and SATS scenarios. A comparison of TB with TS showed no significant differences in controller workload. A comparison of FB with FS also showed no significant differences in controller workload (see Figure 5).

Overall Workload. Phase III ZDC controllers commented that their workload was reduced due to moving aircraft out of their sector more quickly, performing less aircraft holding, eliminating vectoring for approach, eliminating missed approaches as a factor, and eliminating the need for approval clearances.

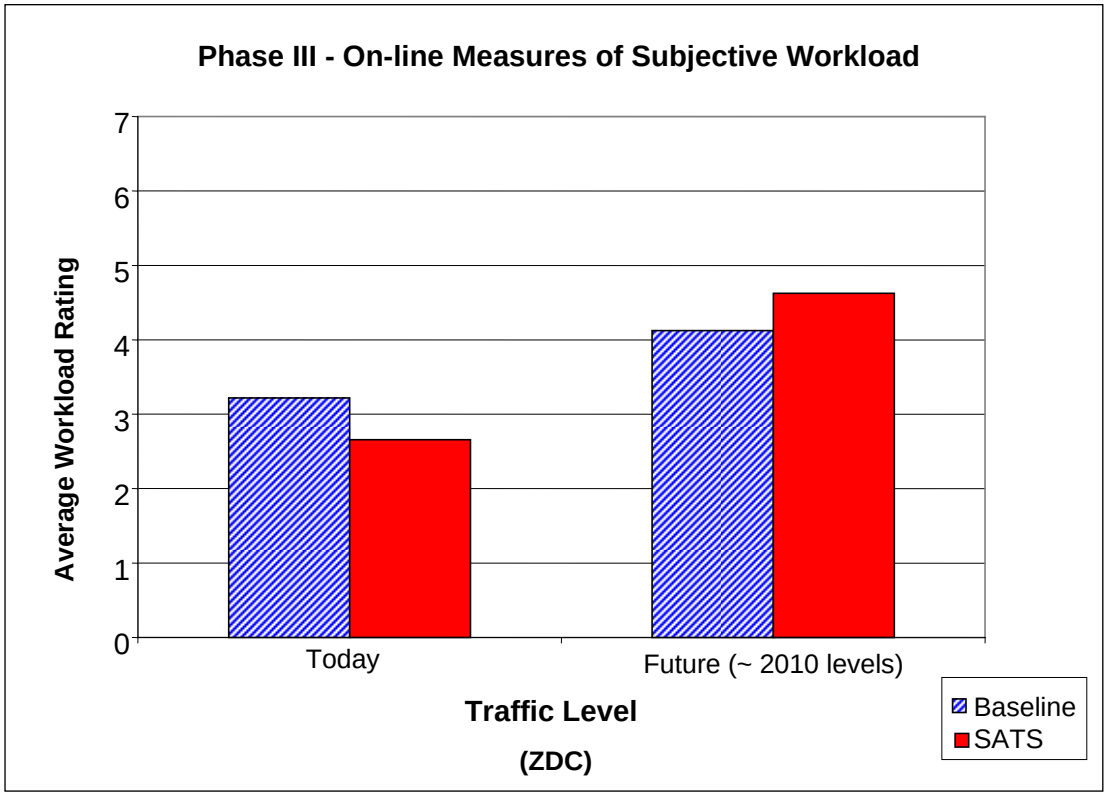

Figure 5. Phase III mean workload ratings for baseline and SATS scenarios.

3.2.2 Situation Awareness

The Post-Scenario Questionnaire included situation awareness (SA) questions developed for the Situation Awareness Rating Technique (SART) (Taylor, 1990). The SART technique elicited ratings on a scale from 1 (low) to 7 (high) on three dimensions of SA. The dimensions were 1) demand of attention, 2) supply of attentional resources, and 3) understanding of the situation. SA was defined as the degree to which the participant was able to perceive the elements in the simulation environment, to comprehend their meaning, and to project their status in the future.

The null hypothesis (H_0) in the analysis was that SART ratings given by controllers in the baseline conditions were the same as the ratings in the SATS conditions. The alternative hypothesis (H_1) was that the SART ratings given by controllers in the baseline conditions were different than the ratings in the SATS conditions. Researchers performed a two-tailed Wilcoxon signed ranks test because this study used related samples, had a small n, and used an ordinal scale which was ranked in order of absolute magnitude.

Phases I, II, and III were analyzed separately with comparisons of TB and TS, and FB and FS. Researchers found no significant differences across the three SA domains with the exception of Phase II, where a comparison of FB and FS showed a significant difference in the Demand on Attentional Resources domain ($T^+ = 10$).

3.2.3 Concept Feasibility

The researchers asked the controllers to provide feedback on the feasibility of SATS HVO from several different perspectives. Controllers provided ratings and comments on the overall feasibility of SATS HVO, the SCA size, the impact of SATS HVO on the ability to control traffic, the potential impact of mixed equipage (not simulated in these studies), and any benefits/disadvantages of SATS HVO. Table 7 shows rating results on some of these issues from the Post-Scenario Questionnaires, and Sections 3.2.3.1 through 3.2.3.3 present additional commentary on concept feasibility issues collected from Post-Simulation Questionnaires and debriefings.

Table 7. Mean Ratings on SATS HVO Concept Feasibility

	Phase I		**Phase II**		**Phase III**	
Concept Feasibility	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***
Feasibility of implementing SATS in simulated airspace **Not Feasible ① ② ③ ④ ⑤ ⑥ ⑦ Very Feasible**	3.25	1.71	6.30	1.50	6.00	1.41
Feasibility of implementing SATS in other airspace within the NAS **Not Feasible ① ② ③ ④ ⑤ ⑥ ⑦ Very Feasible**	6.50	0.58	6.30	0.96	5.75	1.26
Effect of SATS on ability to control traffic **Negative Effect ① ② ③ ④ ⑤ ⑥ ⑦ Positive Effect**	6.25	0.50	6.00	2.00	6.00	2.00
SATS beneficial? **Not Beneficial ① ② ③ ④ ⑤ ⑥ ⑦ Very Beneficial**	5.50	1.73	7.00	0	6.25	1.50

3.2.3.1 Phase I - PHL

Overall Concept Feasibility. Phase I controllers were queried on how feasible the SATS operations would be in both simulated and other airspace within the NAS. All PHL CPCs agreed that the SATS HVO concept, as simulated, could be feasible depending on the geographical location. However, for PHL, the size of the modeled SCA and its impact on surrounding airports and airspace would make its implementation implausible at 40N. Furthermore, PHL controllers found it difficult to justify the 15-mile SCA for such a small amount of traffic. They suggested that if the SCA dimensions were modified, the feasibility of operational implementation could increase for this area.

Overall, Phase I PHL controllers felt that the SATS HVO concept was feasible with modifications. However, the size of the SCA, especially in congested airspace, was a consistent concern. They commented favorably that the concept seemed to help traffic flow and took much of the responsibility from controllers, therefore reducing workload.

SCA Size. Controllers agreed that the SCA took up too much airspace, especially when there were many airports in the surrounding area. They reiterated that routes in and out of PHL would be greatly impacted. Although participants were aware of the generic implementation of the SCA, controllers suggested changing the shape of the SCA, or design predefined routes similar to area navigation routes that do not block large sections of airspace.

Impact on Ability to Control Traffic. PHL controllers responded that controlling SATS aircraft into the SCA was less work since they did not have to control to the ground, and that SATS HVO enabled them to dedicate their attention to the other aircraft under their control.

Impact of Mixed Equipage. Since the SATS concept would be implemented exclusively in IMC conditions, one controller suggested that only equipped aircraft be allowed to arrive at the airports at these times.

Benefits and Disadvantages. Phase I controllers felt the concept had a negative impact in their congested airspace since the SCA encompassed a large area. This impacted their ability to work traffic in the surrounding airspace. The advantages cited were reduced workload, increase of operations, and relief of control responsibility.

3.2.3.2 Phase II - ZDC

Overall Concept Feasibility. Phase II ZDC controllers generally agreed that SATS operations were feasible for DAN and could perhaps be implemented at other small airports. Some controllers cautioned that the large SCA radius would likely limit its use at other more densely located airports. In addition, at least one participant felt that the mixed equipage of SATS and non-SATS aircraft would need to be addressed.

Overall, Phase II ZDC controllers liked the SATS HVO concept, saying it took a lot of workload and responsibility away from the controller. They also felt it could be implemented now at a specific airport in their area where traffic presents a need.

SCA Size. For ZDC controllers, the large amount of airspace occupied by the SCA was less of a problem than PHL controllers due to the lack of congestion and unimpeded traffic flows.

Some controllers felt pre-defined routes would be a better option than the current shape and size of the SCA. These routes could be depicted on the radar display. Some felt that the SCA, as designed in the concept, would require less controller attention than pre-defined routes, but agreed that perhaps a smaller SCA should be implemented.

Impact on Ability to Control Traffic. Phase II controllers generally agreed that the SATS operations made their jobs easier since they were able to hand off the DAN arrivals to the SCA and were no longer responsible for those aircraft. Transferring responsibility of the arrivals to the SCA in effect reduced the amount of time the controllers needed to attend to the arrival traffic. One controller responded that SATS had a negative effect during future operations because “I was running two operations and had too many things to do at once.”

Impact of Mixed Equipage. ZDC controllers felt that the SCA was either on or off, and that the introduction of a non-equipped aircraft would constitute an “off” status.

Benefits and Disadvantages. ZDC Phase II controllers saw benefits to the concept since it eliminated the need for approach clearance instructions. They were in favor of decreasing controller responsibility, allowing more time to spend on other sector responsibilities. They felt that the concept, as simulated, moved traffic more expeditiously, and provided better service to the users.

3.2.3.3 Phase III - ZDC (Linked)

Overall Concept Feasibility. Phase III ZDC controllers responded that SATS implementation would be beneficial for small airports, citing that the operation was easy to execute. However, they expressed concern that the size of the SCA could impact traffic flows to other airports.

Overall, Phase III ZDC controllers viewed the SATS HVO concept favorably. They felt that it was an effective alternative to the one-in, one-out procedure. They also indicated that they liked departing aircraft even when other aircraft were in the SCA. In today's environment, aircraft do not depart if arrivals are present, which results in ground delays that could be extensive. At least one controller commented that discretionary clearances could be problematic. In addition, head-on holding, as proposed by the "t" shape arrival fixes, could be a problem since if one aircraft blunders outside of the holding pattern, separation could be lost.

SCA Size. Phase III responses varied with regard to SCA size as well. Some controllers felt that the SCA was acceptable for the DAN surrounding airspace. Some acknowledged that the SCA's 15-mile radius was too large and could be tailored to specific airspace geometries.

Impact on Ability to Control Traffic. Although one controller responded that the procedure was unfamiliar, most controllers were very positive about transferring the arrivals out of their sector sooner. It eliminated the need to "follow the aircraft to the ground", eliminated clearance delivery, eliminated vectors for sequencing, and greatly reduced transmissions. Another advantage was that the controller could hold two aircraft at the same altitude, reducing the number of used altitudes.

Impact of Mixed Equipage. Phase III controllers felt that the mixed equipped issue would present a variety of problems. There could be confusion as to which aircraft had priority (first come, first served or equipped priority). Unequipped aircraft may need to be vectored for approach. It would require the ability to activate or deactivate the SCA. One approach might be to program a pending request for the airspace for a non-SATS aircraft, allow the last SATS aircraft to land, turn off the SCA and allow the non-equipped aircraft to arrive, and then turn the SCA back on.

Benefits and Disadvantages. ZDC Phase III controllers cited better traffic flows, better service, and reduced workload as benefits of the SATS HVO operation. One controller cautioned that these advantages depended on how the operation affected the system and flows at other locations.

3.2.4 Procedures and Phraseology

The researchers asked the controllers to provide feedback on the simulated SATS HVO procedures and phraseology, including the following: prescribed roles and responsibilities, AMM

sequencing, missed approach procedures, phraseology, transition procedures into and out of SCA, and frequency of communications. It is important to reiterate that once an aircraft entered the SCA, the controllers no longer had any responsibility for that aircraft. Table 8 shows rating results on some of these issues from the Post-Scenario Questionnaires. Sections 3.2.4.1 through 3.2.4.3 present additional comments from the Post-Simulation Questionnaire and debriefings.

Table 8. Mean Ratings on SATS HVO Procedures and Phraseology

	Phase I		**Phase II**		**Phase III**	
Procedures and Phraseology	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***
Acceptability of roles and responsibilities **Not Acceptable ① ② ③ ④ ⑤ ⑥ ⑦ Very Acceptable**	6.50	0.58	7.00	0.00	6.75	0.50
Acceptability of AMM sequencing **Not Acceptable ① ② ③ ④ ⑤ ⑥ ⑦ Very Acceptable**	5.50	1.29	6.30	0.96	6.00	1.41
Acceptability of missed approach procedures **Not Acceptable ① ② ③ ④ ⑤ ⑥ ⑦ Very Acceptable**	6.25	1.50	6.50	1.00	6.75	0.50
Acceptability of SATS phraseology as prescribed in simulation **Not Acceptable ① ② ③ ④ ⑤ ⑥ ⑦ Very Acceptable**	6.25	0.96	5.00	2.16	4.50	1.91
Effectiveness of transition procedures into SATS airspace (arrivals) **Not Effective ① ② ③ ④ ⑤ ⑥ ⑦ Very Effective**	6.50	1.00	6.50	1.00	6.00	1.41
Effectiveness of transition procedures into SATS airspace (departures) **Not Effective ① ② ③ ④ ⑤ ⑥ ⑦ Very Effective**	5.50	2.38	5.50	1.73	5.75	0.96
Effect of SATS on frequency of communications **Decreased Greatly ① ② ③ ④ ⑤ ⑥ ⑦ Increased Greatly**	3.00	0.82	3.3	1.71	2.00	2.00

3.2.4.1 Phase I - PHL

Roles and Responsibilities. Although the PHL CPCs generally agreed that having no responsibility within the SCA was an advantage, they expressed some concern over the issue of roles and responsibilities. Concerns included the need for a clearer definition of who is responsible for ensuring an aircraft has approval to enter the SCA. Many of the controllers were uncomfortable with a pilot's discretion clearance. Also, they felt that the size of the SCA took too much airspace out of the TRACON's responsibility, and that remaining clear of the SCA airspace could be problematic.

When asked whether or not they would be willing to provide limited ATC services within the SCA (e.g., in the event of an emergency)[2], Phase I CPCs felt that to provide any type of service would imply responsibility. If service was required, the majority of controllers would resort back to a one-in, one-out operation and defeat the purpose of the SCA. Controllers felt that sharing responsibility was not an option. They were either responsible for the aircraft or they were not. In addition, controllers felt that the advantage of the SATS concept to ATC was that they were able to drop those aircraft within the SCA and turn their attention to the rest of the air traffic under positive control.

Transition Procedures into and out of SCA. PHL controllers indicated that the transition procedures, in terms of timeliness of aircraft reporting entry approval, the efficiency of arrival operations, the appropriateness of pre-departure and release requests, and climb out on departure, worked well. For departures, some of the controllers felt the procedures needed further refinement. Although the operation essentially relieved the controllers of responsibility, they were unable to issue any control instructions until after the aircraft left the SCA. Therefore, they had little influence on where and when the aircraft would emerge from the automated area. Controllers indicated that they would prefer to hold departures on the ground until the traffic flow allows them to depart. The advantage of the operation, however, was allowing the aircraft to depart without the need to wait for an arrival to report clear of the runway, making the traffic flow more efficient.

AMM Sequencing. One PHL controller felt that at times the AMM sequenced aircraft differently than the controller would. The other controllers felt that the AMM sequenced as briefed it would, with no problems.

Missed Approach Procedures. Since all missed approaches were contained within the SCA and did not require any controller interaction, the PHL controllers commented that the missed approaches were standard, or that they did not even notice them. One controller viewed the procedure positively, saying that keeping the missed approaches within the SCA relieved him from having to re-sequence the aircraft. The controller also felt, however, that the missed aircraft should not get priority to rejoin into the approach.

Phraseology. Two PHL controllers reported no effect of phraseology on operations. One responded that the phraseology was less time-consuming than clearing an aircraft for approach, and the remaining controller reported feeling “tongue-tied” at times.

3.2.4.2 Phase II - ZDC

Roles and Responsibilities. None of the Phase II ZDC controllers indicated any difficulties with the operational roles and responsibilities, citing again that the aircraft were responsible for themselves once in the SCA. When asked whether or not they would be willing to provide limited ATC services within the SCA (e.g., in the event of an emergency), Phase II ZDC controllers felt that this would be an unnecessary burden. Once the aircraft were transferred out

[2] Advanced avionics may improve surveillance capability for both controllers and pilots. Introducing flight deck avionics that enable pilots to see other aircraft may provide the capability of those aircraft to maintain separation. These same capabilities may also provide CPCs with the same on-board information, allowing controllers to display aircraft in non-radar areas where there is currently no service.

of their control, the CPCs did not want responsibility for them, especially if they were not providing sequencing and spacing instructions.

Transition Procedures into and out of SCA. ZDC controllers felt the transition procedures generally worked within the simulated scenarios and reduced delays, since the arriving and departing aircraft were responsible for maintaining separation. However, some of the controllers felt that more standard procedures would have to be developed. Suggestions included having all arrival aircraft hold at a predetermined fix or depart on a prescribed heading at a specified altitude. In addition, one controller felt it was the pilot's responsibility to inform the controller upon approval to enter the SCA in order to cut down on some of the proposed verbiage associated with the procedure. A mixed equipped environment would present a particular challenge for transition procedures.

AMM Sequencing. All Phase II ZDC controllers commented positively regarding the AMM's sequencing, saying that it relieved the controller from making the decision and did so in a timely, effective manner.

Missed Approach Procedures. ZDC Phase II controllers viewed the procedure for missed approaches positively. They did not think the missed approach procedures impacted the controllers, and that the controller could provide uninterrupted service to positively controlled aircraft.

Phraseology. Two ZDC controllers commented that the phraseology included too much verbiage, and that the phraseology increased workload. Specifically, they felt the controller should not have had to ask each aircraft if it had approval to enter the SCA. At least one controller was uncomfortable with giving a "descend at pilot's discretion" clearance without giving the aircraft an altitude to maintain.

3.2.4.3 Phase III - ZDC (Linked)

Roles and Responsibilities. None of the Phase III ZDC controllers indicated any difficulties with the operational roles and responsibilities. When asked whether or not they would be willing to provide limited ATC services within the SCA (e.g., in the event of an emergency), Phase III ZDC controllers indicated they would, but only time-permitting. The issue would then be that the SATS aircraft could expect these services at times when the controller is too busy to provide them, which could then lead to liability issues.

Transition Procedures into and out of SCA. Phase III ZDC controller comments ranged somewhat with regard to this issue. Some CPCs stated that the SCA acted as an automated approach control, thereby reducing responsibility, and therefore workload. However, other CPCs expressed concern with aircraft leaving published holding and descending at their discretion. With regard to departures, controllers indicated that although the transition procedures were much like today's environment, they were less clear than the arrival procedures. One controller suggested that traffic should be cleared to a fix within the SCA, where it would be radar identified, and then fly a published exit procedure to eliminate non-radar clearance void times. They generally felt though, that the operation was an effective way to depart traffic since they did not have separation responsibility.

AMM Sequencing. One Phase III ZDC controller was unsure of how the AMM actually sequenced the aircraft, citing that at times, first-come first-served did not seem to be applied. The other controllers commented that the AMM seemed to work well with minimal delays.

Missed Approach Procedures. Phase III ZDC controllers commented that the procedure was self-contained within the SCA and ultimately removed the controller from the situation. At times, the controller was not even aware that the aircraft had performed a missed approach. It had no effect on the controller's operation and "greatly reduced workload."

Phraseology. Phase III ZDC controllers had mixed comments regarding phraseology. Although unfamiliar, some felt that the phraseology was acceptable, while others stated that it was too wordy. Some controllers commented that issuing discretionary clearances without a specified altitude was inherently dangerous. They also commented that there was too much verbiage. Additional comments included the suggestion to not issue "Expect Further Clearances (EFC)" since the controller has no way to accurately judge when an aircraft could expect an EFC, because it is determined by the AMM. Another comment stated that in the event of lost communication, the pilot should have to divert to an alternate since the controller has no control of the pattern.

3.2.5 Display of Information

Researchers asked the controllers to provide feedback on the adequacy of information displayed to them during SATS operations. They were asked to rate the level of difficulty they had with identifying SATS equipped aircraft and the acceptability of the continuous display of the SCA on their radar scopes. Table 9 presents the rating results.

Table 9. Mean Ratings on SATS HVO Display of Information

	Phase I		**Phase II**		**Phase III**	
Display of Information	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***
Difficulty associated with identifying SATS equipped aircraft **Not Difficult ① ② ③ ④ ⑤ ⑥ ⑦ Very Difficult**	2.33	1.53	4.00	2.94	2.50	3.00
Acceptability of continuous display of SCA **Not Acceptable ① ② ③ ④ ⑤ ⑥ ⑦ Very Acceptable**	5.50	2.38	6.00	1.41	5.50	1.29

Controllers were also queried on other issues related to the display of information. They were asked how they would like to see SATS arrival aircraft data tags depicted on the display (e.g., while in SCA or on an aircraft arrival display list), whether or not they would like a separate display for the SCA, and whether or not they would want the option of turning the SCA on and off (referring to the potential scenario of a non-equipped aircraft wanting to utilize the SATS airport). Sections 3.2.5.1 through 3.2.5.3 present the controller feedback on these issues by simulation phase.

3.2.5.1 Phase I – PHL

SCA Aircraft Display List. Some PHL controllers preferred to see the aircraft data tags until the aircraft landed, however, most preferred to drop the aircraft tags once they entered the SCA since they no longer had separation responsibility.

Separate SCA Display. None of the Phase I PHL controllers wanted a separate SCA display, stating that it would be distracting to have to take their scan away from the primary scope.

Control of Turning SCA On and Off. Controllers preferred to have the SCA on at all times, since turning it on and off would assume greater responsibility and would require them to monitor what aircraft are present in the SCA.

3.2.5.2 Phase II – ZDC

SCA Aircraft Display List. The Phase II ZDC controllers did not want to have the aircraft stay on their display once the aircraft entered the SCA. They suggested that the more workload removed from the controller, the more efficient and expeditious the operation. One suggestion was that the aircraft could be maintained on the User Request Evaluation Tool (URET) display, but not the primary radar display. One controller felt that an SCA aircraft list on the display might be acceptable if it were a preference, but not a responsibility.

Separate SCA Display. As with the PHL controllers, the Phase II ZDC controllers felt that a separate monitor would be more of a burden and distraction than an asset.

Control of SCA Depiction on Radar Scope. ZDC controllers felt that activating and deactivating the SCA might be an easy fix. One CPC suggested that the SCA could be active at certain times of the day.

3.2.5.3 Phase III – ZDC (Linked)

SCA Aircraft Display List. Phase III ZDC controllers did not want inbound or departure lists. Some controllers felt that existing lists are not used today, and that controllers do not need anything additional to take their attention away from their primary display. Other controllers felt that a concealable list might work on the primary scope for emergencies, but since they were not responsible for the aircraft within the SCA, it was not necessary to know what aircraft were located within it.

Separate SCA Display. Phase III controllers did not see a need for a separate display of the SCA.

Control of SCA Depiction on Radar Scope. Half of the ZDC controllers stated they would like the ability to turn the SCA on and off. Some would try to provide the additional services and would keep it on when possible. The other CPCs felt that controllers would turn the display of the SCA on and off differently, and therefore, it would not be an effective approach.

3.2.6 Additional/General Comments

Controllers were given an opportunity to provide any additional comments regarding any aspect of the simulation.

3.2.6.1 Phase I - PHL

Phase I PHL controllers commented that, overall, the SATS concept could be beneficial to the NAS with some modification. Controllers reiterated that there would likely be a problem if SATS operations were implemented as simulated in congested areas such as PHL. One controller suggested that the SCA airspace be designated or configured like Class Bravo or Class Charlie airspace, since a 15-mile radius and altitude to 4,000 ft is a lot of “lost airspace.” A Class Bravo configuration (i.e., upside-down cake shape) would allow for transition closer to the airport. Other comments included that the overall simulation performance and realism was good, but some minor problems had to be resolved. One issue was that the simulation considered the impact on only one sector even though several others would be impacted.

3.2.6.2 Phase II - ZDC

Phase II ZDC controllers reiterated concerns with the SCA size, frequency congestion, excess verbiage (causing greater workload), and data block overlap as problems with the simulated concept. One controller commented that the hand-offs needed to be timelier and that if the controller does not take the hand-offs, the aircraft needs to "spin" just like in real world. Another controller brought up a ‘trust in automation’ issue, saying that it is sometimes difficult for controllers to accept change and to believe that a machine can do the job of a controller. On the positive side, controllers commented that the concept was easy to use, could be beneficial to controllers and users, and reduce holding delays.

3.2.6.3 Phase III - ZDC (Linked)

In the Phase III ZDC sample of CPCs, one controller felt that an additional training scenario (a non-arrival problem) would have helped to adapt to simulator differences, specifically, pilot characteristics, the lack of the fourth line in the data block, the absence of URET, and other unique characteristics of the simulator. Overall, controllers commented that they would like to see a system like this in the NAS.

3.3 Quantitative Measures

The researchers collected quantitative measures throughout this simulation via the TGF Simulator Data Recorder. The Data Reduction and Analysis Tool provided data output on the frequency of communications and arrival rates to allow for comparisons between baseline and SATS scenarios.

3.3.1 Frequency of Communications

Researchers collected the frequency of push-to-talk communications between controllers and pilots as an indicator of workload. Sections 3.3.1.1 through 3.3.1.3 present details of the communications data by simulation phase.

3.3.1.1 Phase I - PHL

A comparison of TB with TS using the Wilcoxon signed ranks test showed no significant differences in frequency of communications required to perform ATC services. A comparison of FS with FS also showed no significant differences in frequency of communications required to perform ATC services (see Figure 6).

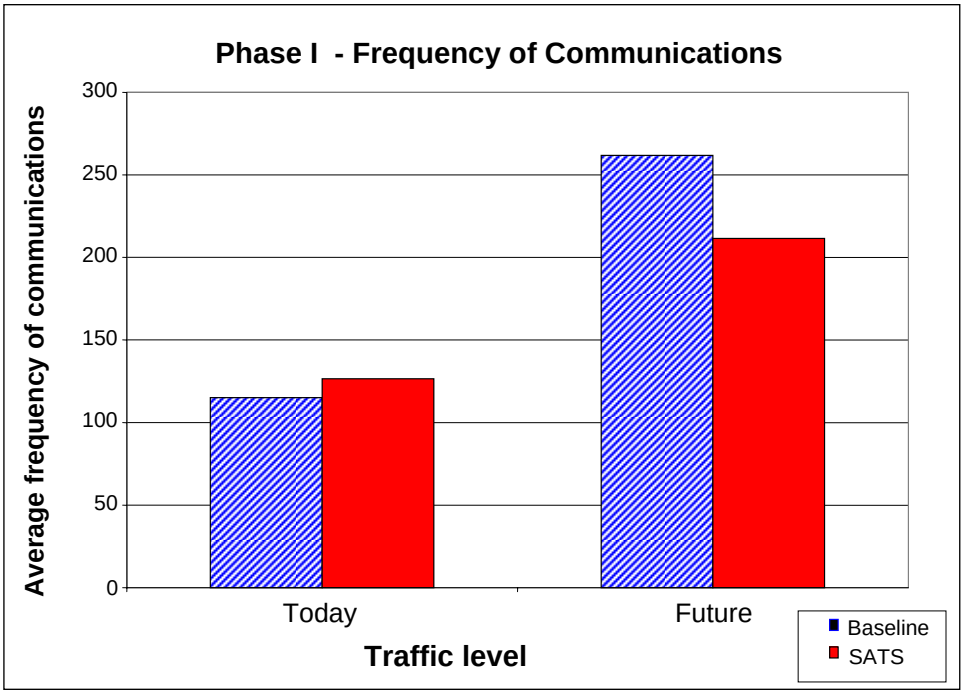

Figure 6. Phase I mean frequency of communications for baseline and SATS scenarios.

3.3.1.2 Phase II – ZDC

A comparison of TB with TS showed no significant differences in frequency of communications required to perform ATC services. A comparison of FS with FS also showed no significant differences in frequency of communications required to perform ATC services (see Figure 7).

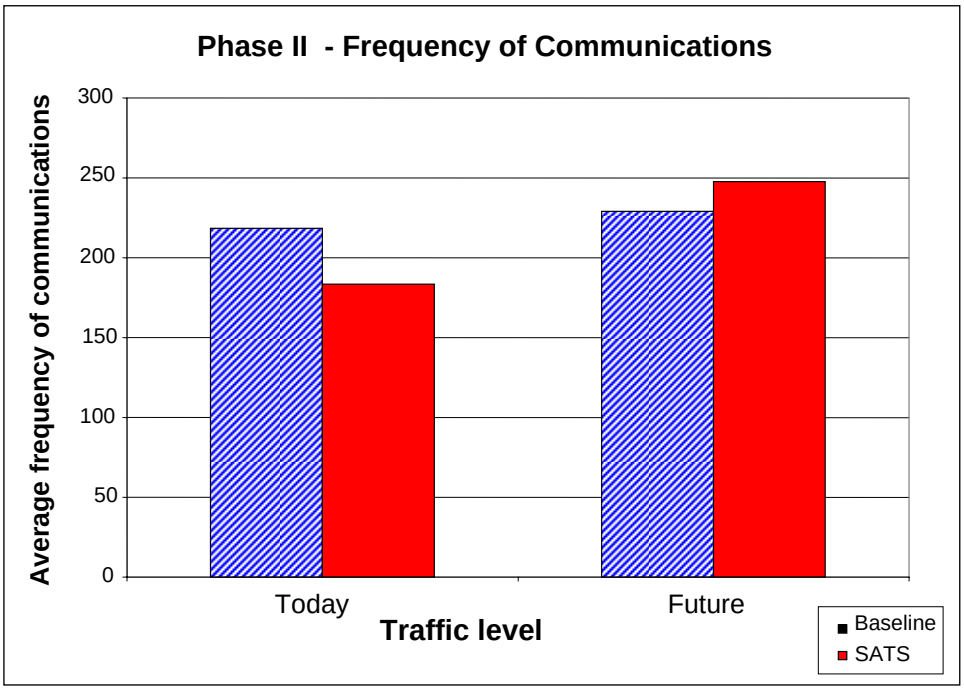

Figure 7. Phase II mean frequency of communications for baseline and SATS scenarios.

3.3.1.3 Phase III - ZDC (Linked)

A comparison of TB with TS showed no significant differences in frequency of communications required to perform ATC services. A comparison of FS with FS also showed no significant differences in frequency of communications required to perform ATC services (see Figure 8).

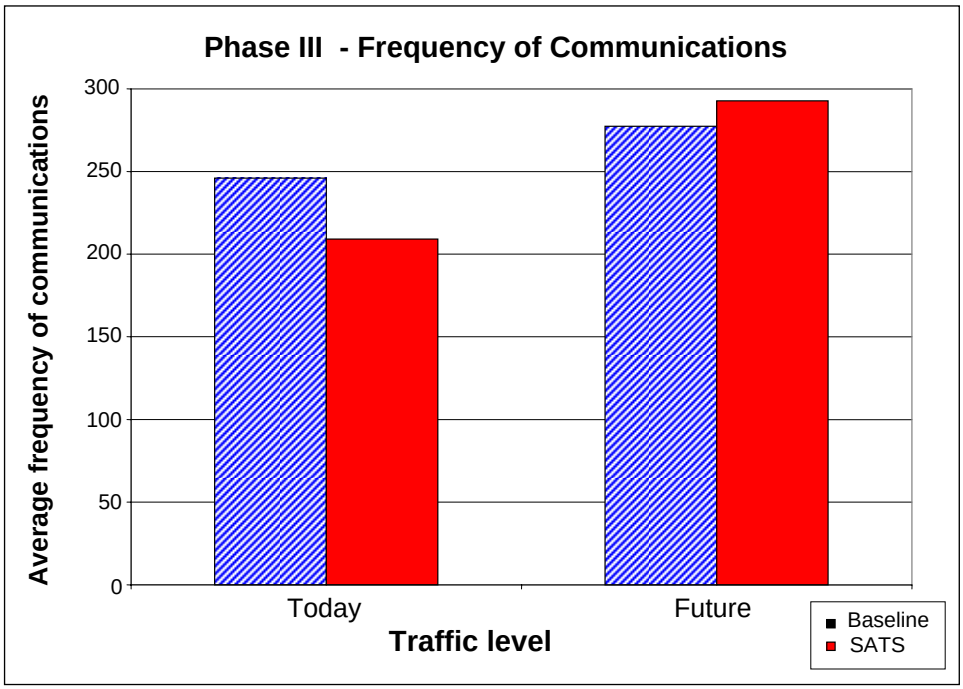

Figure 8. Phase III mean frequency of communications for baseline and SATS scenarios.

3.3.2 Number of Arrivals

An expected outcome of the SATS operations was an increase in the arrivals at airports over the one-in, one-out baseline operation. For comparison purposes, all SATS scenarios continued until all SATS arrivals touched down (i.e., generally 45 minutes). Since allowing all arrivals to land in the baseline scenarios would have considerably lengthened the study, all baseline scenarios ended after approximately 55 minutes. The researchers selected 55 minutes to ensure that the baseline scenarios would be at least as long as the longest SATS scenario. The TGF Simulator Data Recorder collected the number of arrivals for each scenario. Sections 3.3.2.1 through 3.3.2.3 present the arrival data by simulation phase.

3.3.2.1 Phase I- PHL

A comparison of Phase I TB and TS conditions using a two-tailed paired samples t-test showed statistically significant differences in the number of arrivals, $t(3) = -6.97$, $p > .05$, with SATS scenarios resulting in more aircraft arrivals. A comparison of FB and FS also showed statistical significance, $t(3) = -5.75$, $p > .05$, with SATS scenarios resulting in more aircraft arrivals. The mean number of arrivals was as follows: TB 2.25 (*SD* = 0.96), TS 6.75 (*SD* = 0.50), FB 3.50 (*SD* = 0.58), and FS 6.25 (*SD* = 0.96) (see Figure 9).

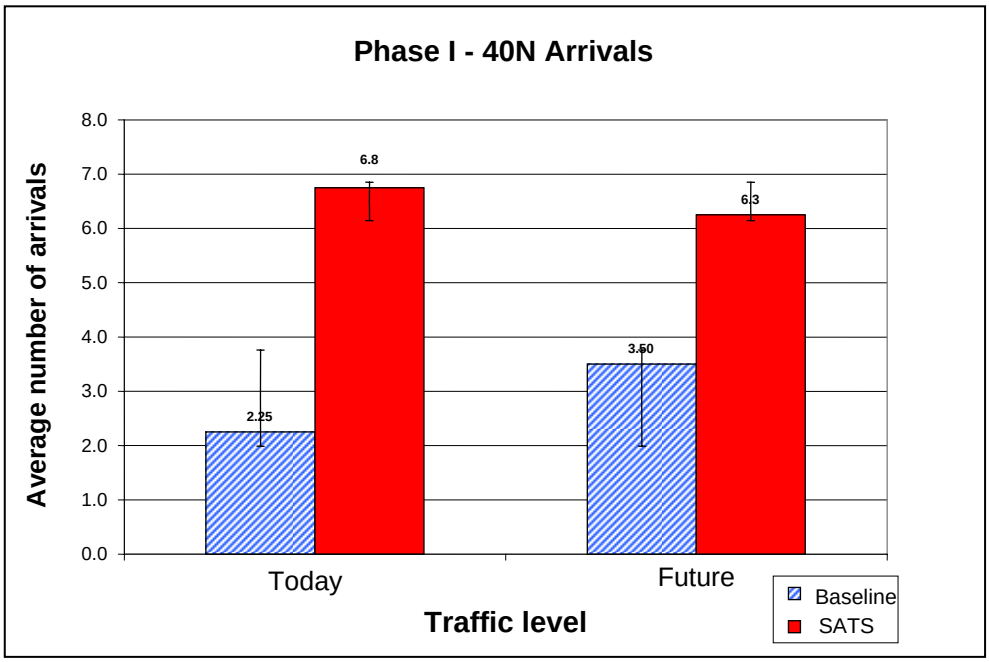

Figure 9. Phase I mean arrival rates for baseline and SATS scenarios.

3.3.2.2 Phase II- ZDC

A comparison of Phase II TB and TS conditions using a paired samples t-test showed statistically significant differences in the number of arrivals, $t(3) = -8.88$, $p > .05$, with SATS scenarios resulting in more aircraft arrivals. A comparison of FB and FS also showed statistical

significance, $t(3) = -8.88$, $p > .05$, with SATS scenarios resulting in more aircraft arrivals. The mean number of arrivals was as follows: TB 2.80 (*SD* = 0.96), TS 7.00 (*SD* = 0.00), FB 2.80 (*SD* = 0.58), and FS 7.00 (*SD* = 0.00) (see Figure 10).

3.3.2.3 Phase III- ZDC (Linked)

A comparison of Phase III TB and TS conditions using a paired samples t-test showed statistically significant differences in the number of arrivals, $t(3) = -7.83$, $p > .05$, with SATS scenarios resulting in more aircraft arrivals. A comparison of FB and FS also showed statistical significance, $t(3) = -6.79$, $p > .05$, with SATS scenarios resulting in more aircraft arrivals. The mean number of arrivals was as follows: TB 3.30 (*SD* = 0.96), TS 7.00 (SD = 0.00), FB 3.30 (SD = 0.50), and FS 6.50 (*SD* = 0.58) (see Figure 11).

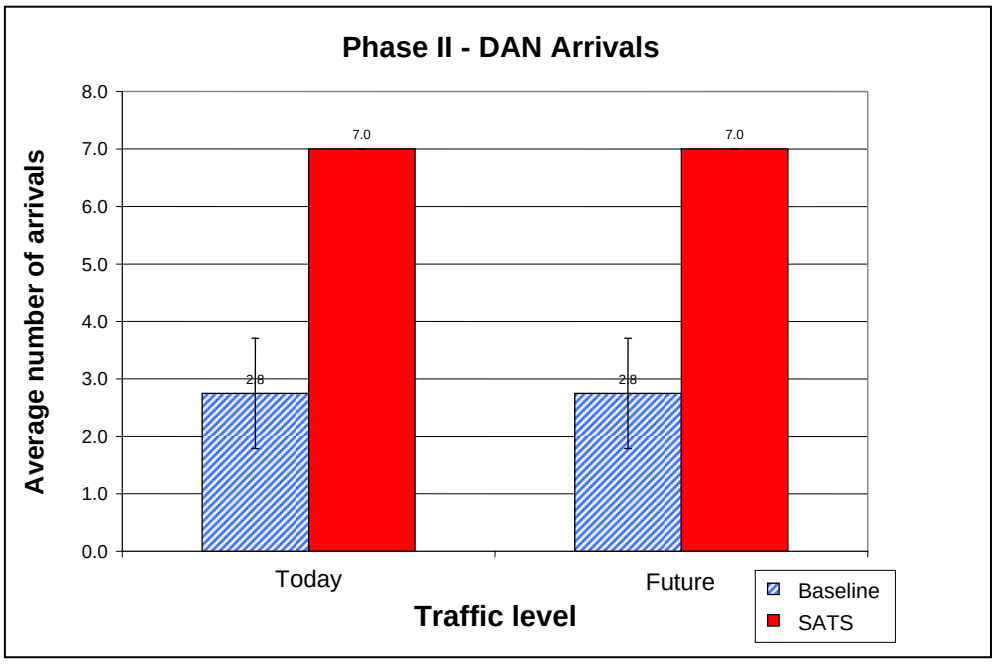

Figure 10. Phase II mean arrival rates for baseline and SATS scenarios.

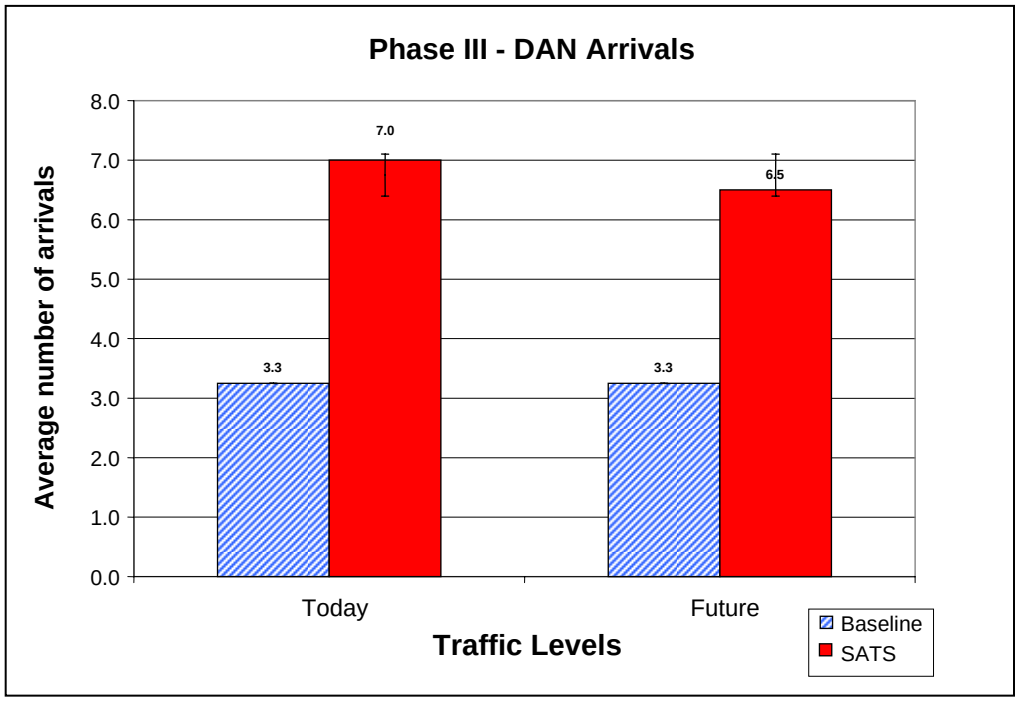

Figure 11. Phase III mean arrival rates for baseline and SATS scenarios.

4. Discussion

These three simulations provided an initial look into the controller perspective on SATS HVO. The transition procedures, airspace development, phraseology, and other SATS specific details developed for the simulations were a first attempt at modeling the SATS concept for the ATC operational environment. As such, it should be noted that the results reported in this document are limited to the assumptions and constraints listed in Section 2.7. Although quantitative data (e.g., frequency of communications, arrival rates) were analyzed, the qualitative data generally provided more insight into the SATS concept, therefore the following was predominately derived from subjective controller responses based on their experience in these simulations.

Overall, SATS HVO was viewed favorably by most of the controllers. By relinquishing control of the arrival aircraft upon entering the SCA, controllers could devote more attention to the other aircraft within the sector. Most controllers agreed in the appropriate airspace, SATS HVO would be beneficial to NAS operations.

Regarding SATS HVO feasibility at their respective facilities, controller responses differed somewhat between the PHL TRACON and ZDC ARTCC controllers. PHL controllers responded that the size of the SCA as simulated would have impacted too much of the traffic flow at PHL, surrounding airports, and adjacent center airspace. ZDC controllers felt that this was not as much of an issue for the DAN airport having much less congested airspace. However, even the ZDC controllers consistently stated that the size of the SCA could be a potential problem in other locations. Controllers discussed the possibility of pre-defined routes as an alternative to an established SCA.

With regard to perceived ATC workload, no statistically significant differences were found between baseline and SATS conditions in any of the simulation phases. Trend data showed that Phase I PHL controller workload ratings were slightly less during SATS scenarios. Given that the traffic levels for both baseline and SATS scenarios were the same; controller reports of reductions in workload directly corresponded to the transfer of responsibility to the flight crews once the SATS aircraft entered the SCA. In essence, the controllers in these simulations were able to handoff aircraft at an earlier time during the SATS scenarios, thereby reducing the number of aircraft within positive control. Transferring SATS aircraft to the SCA also negated the need to deliver clearances to land for those aircraft. In addition, encompassing the missed approach pattern within the SCA eliminated controller concern for missed approaches.

Situation awareness appeared to not be affected by whether SATS operations were in effect or not. The exception to this was seen in the SART results for Phase II, which showed statistically significant results for FB and FS with respect to the Demand on Attentional Resources domain. Because there were no other significant results, this result could have been due to a Type I error. Controller comments indicated that demands on attention might have been reduced due to factors similar to that of the reported reduction in workload. That is, as soon as the controller handed off the aircraft to the SCA, he/she was able to devote more attentional resources to the aircraft under his/her positive control. In any case, situation awareness was, for the most part, not affected by the test conditions.

With respect to SATS HVO simulation procedures and phraseology, controllers in all three simulations consistently identified similar issues. Although the majority of the controllers felt that transferring responsibility to the SCA alleviated workload, they felt that the specific procedures needed further refinement. They reported concern with the “descend at pilot’s discretion” clearance to enter the SCA. Likewise, although the departure procedure eliminated the controllers’ task of separating departure aircraft from arrival traffic, many of the controllers felt that the departure procedures needed further definition. One suggestion was that the aircraft depart to a fix within the SCA where they could be radar identified before flying a published exit procedure.

Controllers differed on their opinions of the proposed phraseology for the SATS operations. Some controllers had no problems with the proposed phraseology, while others felt that there was “too much verbiage.” Specifically, controllers felt they should not have to query the aircraft as to whether or not it received approval to enter the SCA.

Additional CPC feedback indicated that controllers, if given the choice, preferred not to have a separate display for the SCA or an SCA aircraft list displayed on their primary scope. Although some felt turning the SCA on and off could be useful, the majority thought this would equate to greater ATC responsibility. They agreed, though, that this responsibility could be relevant when mixed equipped aircraft (i.e., both SATS equipped and non-SATS equipped) were involved. Most controllers indicated that the mixed equipage, which was not simulated in these studies, should be a focus of future research.

As expected, arrival rates did increase significantly during SATS operations. This was due to fundamental procedural changes, which allow more than one aircraft at a time to enter the non-towered airport’s airspace.

5. Conclusion

Most controllers viewed SATS HVO as favorable due to the transferring of responsibility from ATC to the flight crew once an aircraft entered the SCA. Controllers cited issues that need to be addressed, however, before the SATS HVO concept could be operationally feasible. These issues included the need to define roles and responsibilities for ATC and pilots, refine clearance procedures and phraseology into and out of the SCA, and reduce or tailor the size of the SCA to the specific airspace for which it is sited.

6. Recommendations

Future research of the SATS HVO operational concept is necessary, and should explore the impact of mixed equipped aircraft. Most of the controller participants expressed that the issues surrounding mixed equipage would be significant. In addition, future studies should explore different SCA alternatives, as well as more clearly defined transition procedures.

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Johnson, S. (2002). *Small aircraft transportation system program 2010 concept of operations document*. Unpublished document, National Aeronautics and Space Administration Langley Research Center, Hampton, VA.

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Acronyms

40N	Coatsville/Chester County G.O.Carlson Airport
AMM	Airport Management Module
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATOL	Air Traffic Operations Laboratory
CPC	Certified Professional Controller
CTAF	Common Traffic Advisory Frequency
DAN	Danville Regional Airport
EFC	Expect Further Clearance
FAA	Federal Aviation Administration
FB	Future Baseline
FS	Future SATS
GPS	Global Positioning System
HVO	Higher Volume Operations
IAF	Initial Approach Fix
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LaRC	Langley Research Center
MSL	Mean Sea Level
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
PHL	Philadelphia Air Traffic Control Facility
SA	Situation Awareness
SART	Situation Awareness Rating Technique
SATS	Small Aircraft Transportation System
SCA	Self Controlled Area
SDL	Simulation Display Laboratory
SME	Subject Matter Expert
SPW	Simulation Pilot Workstation

TB	Today Baseline
TGF	Target Generation Facility
TRACON	Terminal Radar Approach Control
TS	Today SATS
URET	User Request Evaluation Tool
VFR	Visual Flight Rules
WAK	Workload Assessment Keyboards
WJHTC	William J. Hughes Technical Center
ZDC	Washington Air Route Traffic Control Center

Appendix A

Controller Consent Form

Consent Form

I, _____, understand that National Aeronautics Space Administration (NASA) Langley Research Center and the Federal Aviation Administration (FAA) William J. Hughes Technical Center sponsor and direct this study, entitled *Air Traffic Controller Feasibility Assessment of SATS HVO Transition Procedures*.

Nature and Purpose:

I agree to volunteer as a participant in the study cited above. I understand the purpose of *Air Traffic Controller Feasibility Assessment of SATS HVO Transition Procedures* study is to assess controller workload and acceptability of the SATS HVO transition procedures. If the procedure is determined to not be feasible within the existing airspace, I will make recommendations/ suggestions with respect to airspace, procedural, phraseology, route changes, or other relevant feedback that could enable a successful SATS HVO operation. I will also identify potential impacts of such changes on surrounding airspace.

Participant Responsibilities:

The study will emulate operational air traffic conditions in Sector 22 of Washington Air Route Traffic Control Center (ARTCC). I will monitor and control aircraft as I would in the field. I will provide workload ratings when prompted and complete questionnaires after each scenario and at the completion of the simulation.

Discomforts and Risks:

There are no expected discomforts or risks associated with this experiment.

Participant Assurances:

I understand that my participation in this study is completely voluntary. I understand that if new findings develop during the course of this research that may relate to my decision to continue to participation, I will be informed. I understand that I can withdraw from the study at any time without penalty or loss of benefits to which I may be entitled. I also understand that the researcher of this study may terminate my participation if he/she feels this to be in my best interest.

I understand that records of this study are strictly confidential, and that I will not be identifiable by name or description in any reports or publications about this study. Video and audio recordings are for use within NASA and the WJHTC only. Any of the materials that may identify me as a participant cannot be used for purposes other than internal to NASA or the WJHTC without my written permission.

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

Research Participant: _____Date: _____

Appendix B

Proposed Phraseology and Procedures

SATS Arrivals	
Event:	**Vertical entry into SATS airspace.** **Aircraft enters the ATC facility Sector/Terminal area in which the destination SATS airport Is located, proceeding to the IAF on "T" approach requested by the pilot and delay is anticipated at the clearance limit prior to aircraft being able to enter the SCA**
Pilot:	"(Approach/Center), (A/C ID), AT or DESCENDING TO (altitude), WITH (airport) WEATHER, INITIAL APPROACH FIX (fix)."
ATC:	"(A/C ID), (Approach/Center), CLEARED TO (fix), HOLD (direction), AS PUBLISHED, MAINTAIN (altitude)." If necessary: "EXPECT FURTHER CLEARANCE (time)."
Note:	The assigned altitude will be the first available holding altitude above the SCA. If necessary, issue detailed holding instructions)
Event:	**Aircraft is at an altitude immediately above the SCA**
ATC:	"(A/C ID) (Approach/Center), ADVISE WHEN YOU RECEIVE APPROVAL TO ENTER THE SCA."
Pilot:	"(A/C ID) HAS APPROVAL TO ENTER THE SCA."
ATC:	"(A/C ID) DESCEND AT PILOT'S DISCRETION, REPORT ENTERING THE SCA."
Pilot:	"(A/C ID) WE ARE DESCENDING OUT OF (altitude)."
Event:	**Aircraft enters the SCA**
Pilot:	"(A/C ID) IS ENTERING THE SCA."
ATC:	"(A/C ID) RADAR SERVICES TERMINATED. CHANGE TO ADVISORY FREQUENCY APPROVED." (Pilot assumes separation responsibility).

SATS Arrivals (cont'd)	
Event:	**Horizontal entry into SATS airspace.** **SATS equipped aircraft is inbound to the IAF on the "T" approach for the destination SATS airport, below the upper limit of the SCA. Aircraft enters the ATC facility Sector/Terminal area in which the SATS airport is located and requests entry into the SCA at an altitude below the vertical limit of the airspace):**
Pilot:	"(Approach/Center), (A/C ID), WE ARE LEVEL AT (altitude), WITH (airport) WEATHER, INITIAL APPROACH FIX (fix)."
ATC:	"(A/C ID), (Approach/Center), ADVISE WHEN YOU RECEIVE APPROVAL TO ENTER THE SCA. MAINTAIN (altitude) UNTIL ENTERING THE SCA."
Pilot:	**"(**A/C ID) HAS APPROVAL TO ENTER THE SCA."
ATC:	"(A/C ID) REPORT ENTERING THE SCA."
Event:	**Aircraft enters the SCA**
Pilot:	"(A/C ID) IS ENTERING THE SCA."
ATC:	"(A/C ID), RADAR SERVICE TERMINATED. CHANGE TO ADVISORY FREQUENCY APPROVED." ***(Pilot assumes separation responsibility).***

SATS Departures

Event: Aircraft requests pre-departure clearance

Pilot: "(Approach/Center), (A/C ID), REQUEST CLEARANCE TO (destination airport)."

ATC: "(A/C ID), (Approach/Center), CLEARED TO THE (destination) AIRPORT AS FILED MAINTAIN (altitude), EXPECT (altitude)(xx) MINUTES AFTER DEPARTURE, DEPARTURE FREQUENCY WILL BE (freq.), SQUAWK (transponder code)."

Note: At locations without ATC Service, but within a Class E surface area-specify if necessary: "WHEN ENTERING CONTROLLED AIRSPACE, PROCEED DIRECT (departure fix)."

ATC: "A/C ID), CLEARANCE VOID IF NOT OFF BY (time)." (If required "IF NOT OFF BY (Clearance void time), ADVISE (Approach/Center) NOT LATER THAN (Time) OF INTENTIONS, TIME (in hours, minutes and the nearest quarter minute)."

Event: Pilot read back of clearance

Pilot: "*(Approach/Center), (A/C ID) (read back of clearance)."*

ATC: *"(A/C ID), READ BACK CORRECT." (or advise of corrections)*

Event: Aircraft requests release

Pilot: *"(*Approach/Center), (A/C ID), REQUEST RELEASE, DEPARTING (airport name)."

ATC: "(A/C ID), RELEASED FOR DEPARTURE." Or "(A/C ID), HOLD FOR RELEASE, EXPECT (time in hours and/or minutes) DEPARTURE DELAY."

Note: ATC would advise of any delays or relay any pertinent information at this time. Optional: If ground communications capability exists: Pilot takes runway, advises ATC "(A/C ID) rolling."

Event: Pilot contacts ATC climbing out on departure

Pilot: "(Approach/Center), (A/C ID), AIRBORNE, LEAVING (altitude) FOR (assigned altitude)."

Note: This may be an altitude above the SCA, if so assigned in pre-departure clearance.

ATC: *"(*A/C ID), (Approach/Center), REPORT LEAVING THE SCA."

Pilot: "(A/C ID), LEAVING THE SCA."

ATC: "(A/C ID), RADAR CONTACT."

Appendix C

Background Questionnaire

Background Questionnaire

Participant Code_____ Facility _____

Date _____

Instructions:

This questionnaire is designed to obtain information about your background and experience as a Certified Professional Controller. The information will be used to describe the participants in this study as a group. Your identity will remain anonymous.

Demographic Information and Experience

1. What is your **age**?	_____ years
2. What is your **total experience as a controller** (in any control position and geographic location)?	_____ years _____ months
3. What is your **total experience as a ZDC** controller?	_____ years _____ months
4. Are you currently **certified on Sector 22** operations?	_____ Yes _____ No
5. How long have you **actively controlled traffic** in the en route environment?	_____ years _____ months
6. How many of the **past 12 months** have you actively controlled traffic?	_____ months

Thank you for your participation!

Appendix D

Post-Scenario Questionnaire

Post-Scenario Questionnaire

Participant Code_____ Facility _____

Scenario _____

Instructions:

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

1. Rate your **overall level of ATC performance** during this scenario.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good
2. Rate your **ability to move aircraft through the sector** during this scenario.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good
3. How would you rate the **overall level of efficiency** of this operation?	Very Low	① ② ③ ④ ⑤ ⑥ ⑦	Very High
4. Rate the **difficulty** of this scenario.	Very Easy	① ② ③ ④ ⑤ ⑥ ⑦	Very Difficult
5. Rate the **performance of the simulation pilots** in terms of their responding to your control instructions and providing a realistic air traffic environment.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good

The term ***situation awareness*** refers to how well you were able to perceive the elements in the environment, to comprehend their meaning, and to project their status.

6. Rate your **overall level of situation awareness** during this scenario.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good
7. Rate your **situation awareness for current aircraft locations** during this scenario.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good
8. Rate your **situation awareness for projected aircraft locations** during this scenario.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good
9. Rate your **situation awareness for potential loss-of-separation** during this scenario.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good

The following questions pertain to situational awareness on three dimensions:
1) Demand on attentional resources, 2) Supply of attentional resources, and
3) Understanding.

10.	**Demand of attention** How demanding was the scenario on your attention?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
11.	**Instability of situation** How likely to change was the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
12.	**Complexity of situation** How complicated was the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
13.	**Variability of situation** How variable were the factors in the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
14.	**Supply of attention resources** How much attention did you have available to devote to the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
15.	**Arousal** How alert and ready for action did you feel throughout the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
16.	**Concentration of attention** How concentrated were you on the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
17.	**Division of attention** How divided was your attention among the elements in the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
18.	**Spare mental capacity** How much attention did you have left over to deal with new events, should they happen?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
19.	**Understanding of the situation** How well did you understand the situation as it was in this scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
20.	**Information quantity** How much information were you able to obtain throughout the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
21.	**Information quality** How good or valuable was the information that you obtained throughout the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High
22.	**Familiarity** How knowledgeable and familiar were you with the events and elements in the scenario?	Low	① ② ③ ④ ⑤ ⑥ ⑦	High

The term ***workload*** refers to both the cognitive and physical demands imposed by your tasks.

23.	Rate your **overall mental workload** during this run. (Mental workload refers to planning, coordination, etc.).	Very Low	① ② ③ ④ ⑤ ⑥ ⑦	Very High

A. Were there any tasks that you would normally perform when controlling traffic that you were unable to perform during this particular scenario? (Check one) Yes ☐ No ☐

B. If you answered "Yes" to part A, please list the tasks you were unable to complete.

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24.	Rate the workload you experienced with **ground-to-air communications** during this run.	Very Low	① ② ③ ④ ⑤ ⑥ ⑦	Very High

25.	Rate the workload you experienced with **controlling aircraft into and out of the SCA** during this run.	Very Low	① ② ③ ④ ⑤ ⑥ ⑦	Very High

Appendix E

Post-Simulation Questionnaire

ATC Post Simulation Questionnaire

Participant Code_____ Facility _____

Scenario _____

Instructions:

Please answer the following questions based upon your experience in the demonstration. Your identity will remain anonymous.

Concept

1.	From an air traffic control perspective, how **feasible would it be to implement** Small Aircraft Transportation System (SATS) High Volume Operations (HVO) *in the airspace simulated* in this demonstration?	Not At All Feasible	① ② ③ ④ ⑤ ⑥ ⑦	Very Feasible

2.	From an air traffic control perspective, how **feasible would it be to implement** SATS HVO *in any other airspace in the NAS*?	Not At All Feasible	① ② ③ ④ ⑤ ⑥ ⑦	Very Feasible

A. Please elaborate on your responses to Questions 1 and 2.

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3.	What effect, if any, did the SATS HVO have on your **ability to control traffic**?	Negative Effect	① ② ③ ④ ⑤ ⑥ ⑦	Positive Effect

A. Please explain how the SATS HVO operation **affected your ability to control traffic**, if at all.

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4.	Based upon your experience in the simulation, do you feel that **implementing SATS HVO** could be beneficial?	Not At All Beneficial	① ② ③ ④ ⑤ ⑥ ⑦	Very Beneficial

A. What are the **advantages and disadvantages** of the SATS HVO as you see them?

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Procedures/Phraseology

5.	Were the **roles and responsibilities** imposed on **ATC to allow for SATS HVO** in the simulation acceptable?	Not Acceptable	① ② ③ ④ ⑤ ⑥ ⑦	Very Acceptable

A. Please provide examples where **SATS HVO roles and responsibilities were unacceptable**, if at all.

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6.	How **effective were the SATS HVO transition procedures** specifically for SATS ***arrival* traffic** (e.g. timeliness of aircraft reporting Self Controlled Area (SCA) entry approval, efficiency of aircraft arrival operations)?	Not At All Effective	① ② ③ ④ ⑤ ⑥ ⑦	Very Effective

A. Please explain.

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7.	How **effective were the SATS HVO transition procedures** specifically for SATS ***departure*** **traffic** (e.g. appropriateness of aircraft pre-departure requests, release requests, climb out on departure)?	Not At All Effective	① ② ③ ④ ⑤ ⑥ ⑦	Very Effective

A. Please explain.

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8.	Was the **sequencing provided by the AMM** to aircraft entering the SCA during the simulation acceptable?	Not At All Acceptable	① ② ③ ④ ⑤ ⑥ ⑦	Very Acceptable

A. Please explain.

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9.	Was the procedure for **executing missed approaches** within the SCA during the simulation acceptable?	Not At All Acceptable	① ② ③ ④ ⑤ ⑥ ⑦	Very Acceptable

A. Please explain.

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10.	What effect, if any, did the SATS HVO have on the **frequency of communications**?	Decreased Greatly	① ② ③ ④ ⑤ ⑥ ⑦	Increased Greatly

11.	Was the **phraseology** used to support SATS HVO **during the simulation acceptable**?	Not At All Acceptable	① ② ③ ④ ⑤ ⑥ ⑦	Very Acceptable

A. Explain how the **SATS HVO phraseology affected operations**, if at all. If any phraseology was not feasible, please explain.

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Workload

The term ***workload*** refers to both the cognitive and physical demands imposed by your tasks.

12.	What **effect**, if any, did the SATS HVO operation have **on your workload** in comparison to today's conventional non-radar procedures?	Decreased Greatly	① ② ③ ④ ⑤ ⑥ ⑦	Increased Greatly

A. Explain how the **SATS HVO affected your workload**, if at all.

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Display

13.	Rate the difficulty of **identifying SATS equipped aircraft** on the display during the simulation.	Not At All Difficult	① ② ③ ④ ⑤ ⑥ ⑦	Very Difficult

A. Do you have any **suggestions** as to how to better identify the SATS equipped aircraft?

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14.	Was the **continuous display of the Self Controlled Area (SCA) during SATS runs** acceptable?	Not At All Acceptable	① ② ③ ④ ⑤ ⑥ ⑦	Very Acceptable

Realism

15.	In general, how **realistic was the simulation**?	Very Unrealistic	① ② ③ ④ ⑤ ⑥ ⑦	Very Realistic

16.	Rate the **realism of the simulation traffic** compared to actual NAS traffic.	Very Unrealistic	① ② ③ ④ ⑤ ⑥ ⑦	Very Realistic

17.	Rate the **realism of the simulation airspace** compared to actual NAS airspace.	Very Unrealistic	① ② ③ ④ ⑤ ⑥ ⑦	Very Realistic

18.	Rate the overall **performance of the simulation-pilots** during this simulation.	Very Poor	① ② ③ ④ ⑤ ⑥ ⑦	Very Good

19.	To what extent did the **WAK (workload assessment keypad) interfere with your performance**?	Not At All	① ② ③ ④ ⑤ ⑥ ⑦	A Great Deal

20.	Please rate the **adequacy of the training** you received for the simulation.	Not At All Adequate	① ② ③ ④ ⑤ ⑥ ⑦	Very Adequate

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

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Thank you for your participation!