

# AIR TRAFFIC CONTROL STUDIES OF SMALL AIRCRAFT TRANSPORTATION SYSTEM OPERATIONS

*Adam Greco, Sherri Magyarits, Scott Doucett,  
Federal Aviation Administration, William J. Hughes Technical Center,  
Atlantic City International Airport, NJ*

## 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. For the complete final test report, see [1].

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 [1]. 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.

## 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 [2]. 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 [3], 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 [3]. 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 [3].

## **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.

## **Simulation Overviews**

The three simulations will be referred to as Phases I, II, and III throughout this paper, and they are briefly described in the following sections. 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.

### ***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.

### ***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.

### ***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) 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.

## **Method**

### ***Participants***

#### **Certified Professional 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.

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.

#### **Simulation 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 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.

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

### ***Test Facility and Equipment***

#### **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.

#### **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.

#### **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.

#### **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.

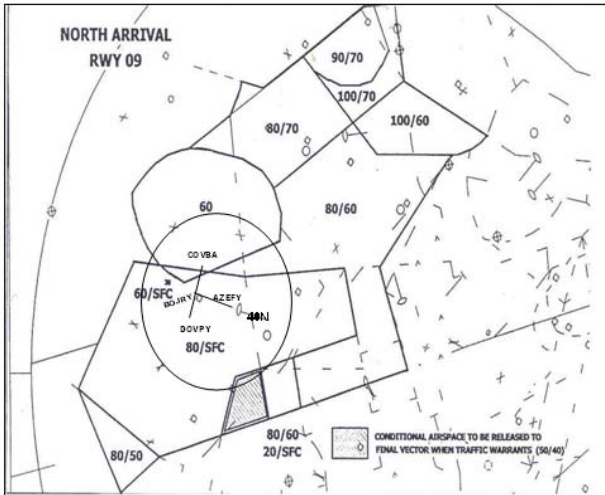
### ***Airspace***

#### **Philadelphia 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.



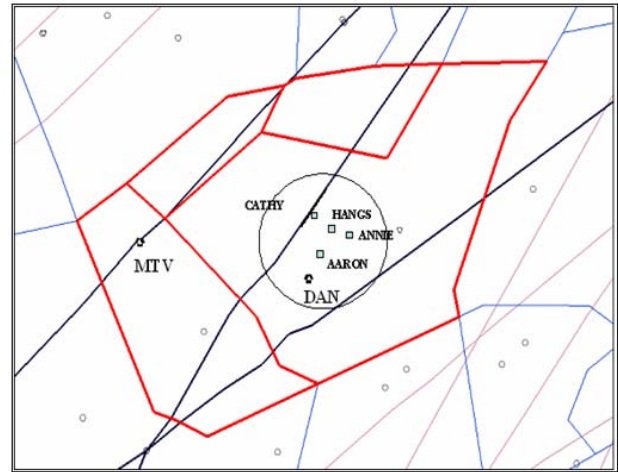
**Figure 1. Coatesville/Chester County Airport**

**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**

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

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.

**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).

**Procedure**

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.

**CPC Responsibilities**

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.

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 were intended to address the changes in these tasks. To the extent possible, phraseologies and procedures currently used in the NAS were used.

#### **Simulation Pilot Responsibilities**

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.

#### **Simulation Assumptions and Limitations**

The three simulations discussed in this paper 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.

## **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. 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. To supplement that data, the researchers collected several system performance measures related to communications and arrival rates.

## ***Qualitative Feedback***

### **Workload**

Although during-the-run workload ratings showed no significant differences between conditions, Phase I PHL 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. They commented that transferring separation responsibility, though, 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.

In Phase II, during-the-run workload ratings were higher (more in the moderate range) than in Phase I, but the Phase II ratings showed no significant differences between SATS and non-SATS test conditions. Phase II ZDC controllers did comment 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. They 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.

In Phase III, during-the run workload ratings were also in the moderate range, but were not significantly different between test conditions. 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.

### **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.

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 equipment 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. Transferring responsibility of the arrivals to the SCA in effect reduced the amount of time the controllers needed to attend to the arrival traffic. They also felt it could be implemented now at a specific airport in their area where traffic presents a need.

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 cited better traffic flows, better service, and reduced workload as benefits. 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. Phase III controllers felt that the mixed equipped issue could 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.

### **Procedures and Responsibilities**

Although the Phase I 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. 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)<sup>1</sup>, 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. Phase I 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.

Phase I 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-

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<sup>1</sup> 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.



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.

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

Phase II 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.

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.

Phase III ZDC controller comments ranged somewhat with regard to the issue of transition procedures. 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.

#### **Display of Information**

Most Phase I, II, and III CPCs preferred to drop the aircraft tags once they entered the SCA, since they no longer had separation responsibility. In addition, most controllers did not see the need for a separate display of SATS operations-related information.

### ***Quantitative Measures***

#### **Frequency of Communications**

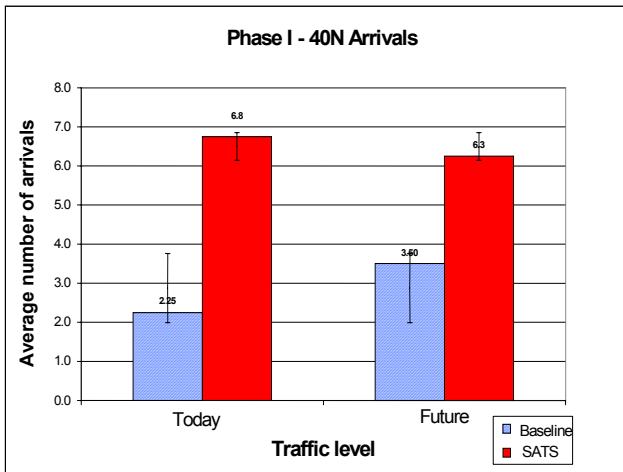
Researchers collected the frequency of push-to-talk communications between controllers and pilots as an indicator of workload. In all three simulation phases, results using Wilcoxon signed ranks tests showed no significant differences between SATS and non-SATS scenarios in baseline traffic levels and in future levels.

#### **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

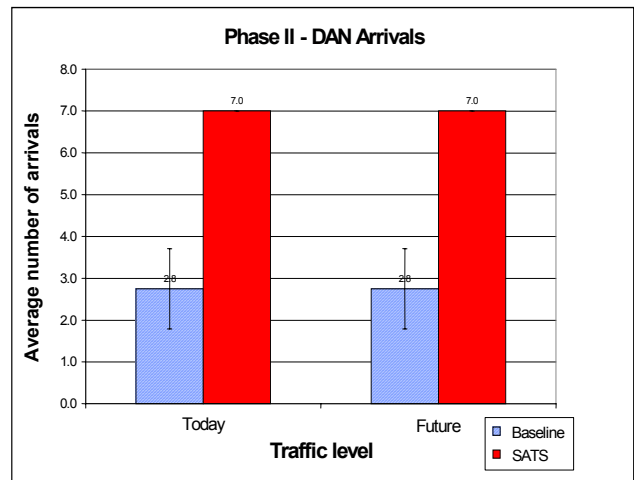
lengthened the study, all baseline scenarios ended after approximately 55 minutes. The researchers selected 55 minutes to ensure that the baseline scenarios would be at least as long as the longest SATS scenario.

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 3).



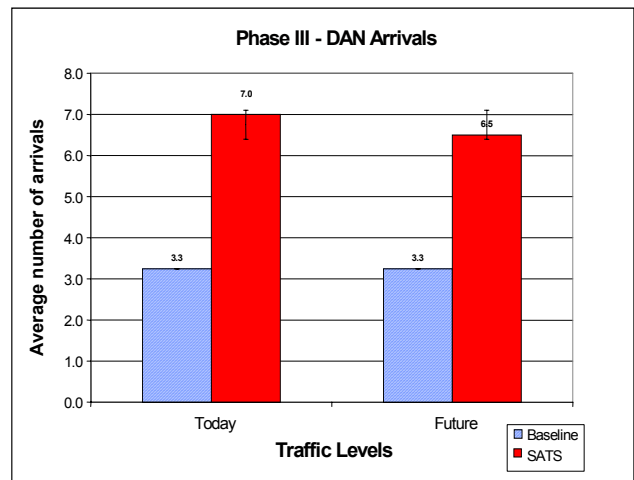
**Figure 3. Phase I Mean Arrival Rates**

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 4).



**Figure 4. Phase II Mean Arrival Rates**

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 5).



**Figure 5. Phase III Mean Arrival Rates**

## 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 previously described.

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.

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.

## 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.

## 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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