

# Considerations in the Integration of Small Aircraft Transportation System Higher Volume Operations (SATS HVO) into the National Airspace System (NAS)

Gary W. Lohr and Dan Williams  
NASA Langley Research Center, 20 West Taylor Street, Hampton, VA 23681

Terence Abbott  
Booz Allen Hamilton, 8283 Greensboro Drive, McLean, VA 22102

Brian Baxley  
NASA Langley Research Center, 20 West Taylor Street, Hampton, VA 23681

Adam Greco  
FAA William J. Hughes Technical Center, Atlantic City International Airport,  
Atlantic City, New Jersey 08405

Richard Ridgway  
L-3, Titan, 5218 Atlantic Ave., 3rd Floor Mays Landing, NJ 08330

**The Small Aircraft Transportation System Higher Volume Operations (SATS HVO) concept<sup>(Ref. 1)</sup> holds the promise for increased efficiency and throughput at many of the nations under-used airports. This concept allows for concurrent operations at “uncontrolled” airports that under today’s procedures are restricted to one arrival or one departure operation at a time, when current-day IFR separation standards are applied. To allow for concurrent operations, SATS HVO proposes several fundamental changes to today’s system. These changes include: creation of dedicated airspace, development of new procedures and communications (phraseologies), and assignment of roles and responsibilities for pilots and controllers, among others. These changes would affect operations on the airborne side (pilot) as well as the groundside (controller and air traffic flow process). The focus of this paper is to discuss some of the issues and potential problems that have been considered in the development of the SATS HVO concept, in particular from the ground side perspective. Reasonable solutions to the issues raised here have been proposed by the SATS HVO team, and are discussed in this paper.**

## I. Background

### A. SATS HVO Concept

The Small Aircraft Transportation System Higher Volume Operations (SATS HVO) concept is well documented in several other reports; however the essential elements are repeated in this paper as necessary for background information.

Projected increases in air traffic over the next 10 – 15 years<sup>(Ref. 2)</sup> require solutions for accommodating that traffic beyond continued reliance on airports that are currently over-used. A viable solution to this problem is to take advantage of under-used airports, many of which are uncontrolled, with little or no radar coverage. As such, the separation standards applied when instrument approaches are in use are inherently conservative and inefficient. The SATS HVO concept proposes solutions to this inefficiency.

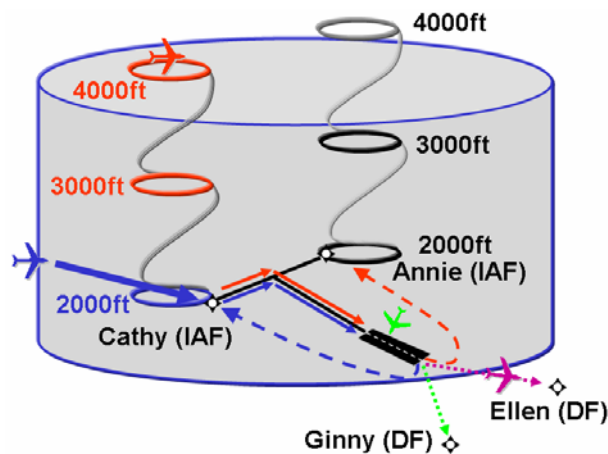
Key to this concept is the use of a newly defined area of flight operations called a Self-Controlled Area (SCA), established during periods of IMC around “SATS designated airports” (i.e., non-towered, limited or no radar services). The decision-making environment assumed for this concept leaves the majority of the decision-making responsibility with the pilot, and includes development of the necessary procedures, tools, and information to enable safe operations within the SCA.

Within the SCA, pilots would have the ability and responsibility to maintain separation between themselves and other similarly equipped airplanes, using advanced airborne systems. Aircraft operating in this airspace would need special avionics, e.g., Automatic Dependent Surveillance-Broadcast (ADS-B), a two-way data link, and appropriate self-separation tools in order to participate. This concept would also require a new, ground-based automation system called the Airport Management Module (AMM), which would typically be located at the airport. The AMM would provide an arrival sequence to the arriving aircraft, and broadcast the total number of aircraft arriving into the SCA. It would not, however, provide separation, altitude assignments, or sequence departures.

This proposed operational concept emphasizes the integration with the current and planned near-term NAS. The fundamental design approach was to simplify procedures and systems requirements. It was also required that any additional ATC workload was minimized, and that enroute procedures were compatible with today's ATC system. A joint NASA Langley Research Center and FAA Technical Center simulation study focused on the SATS HVO and ATC transitions (i.e., SCA airspace design, and controller-pilot SCA transition procedures) to ensure that additional ATC workload was minimized and that SATS HVO integrated well with today's ATC system. Controller acceptance of SATS HVO has been positive; the results and reference for this study are provided later in this paper.

The SATS HVO concept is considered a starting point or "template" for additional designs and analyses. To date, the development focus has been on providing an operational concept that is safe, would enable more than one operation at a time, and would not require significant ground infrastructure costs or improvements.

Under SATS HVO, an aircraft would approach a SATS airport on an IFR clearance granted by ATC to a transition fix. The clearance at this fix would usually be at an altitude above the SCA, however, the first aircraft cleared for entry into the SCA may enter laterally. This fix is also an Initial Approach Fix (IAF) for an instrument approach procedure<sup>1</sup>. Prior to reaching the fix, the pilot requests a landing assignment from the AMM through their onboard system. The AMM responds with the SCA entry procedure (standby, vertical, or lateral), relative sequence information (follow <Callsign>), and Missed Approach Hold Fix assignment (MAHF, e.g. ANNIE or CATHY). The AMM only sequences arrivals (including missed approach aircraft), not departures. Nominally, up to four arriving aircraft are allowed in the SCA before denying entry (issuing a "standby"), though this constraint can be affected by local airspace restrictions<sup>2</sup>. Following their entry assignments and the HVO procedure to "descend to lowest available altitude," pilots are deconflicted from other arriving aircraft (i.e., the AMM reserves slots at one of the MAHFs for all aircraft at the IAFs).



**Figure 1. SATS HVO Example**

<sup>1</sup> GPS-T instrument approach procedures were chosen as a basis for this concept, although other instrument approach procedures could be used.

<sup>2</sup> The number of arriving aircraft, including those executing a missed approach, is limited by the holding altitudes available for the approach. Fig. 1 shows the nominal approach design with four potential holding segments.

Many of the features of the GPS-T based SATS HVO concept are depicted in Figure 1. SATS arrivals (**Red** and **Blue** aircraft) to the IAFs are shown with alternating missed approaches, and departures (**Green** and **Purple** aircraft) are shown near the Departure Fixes (DFs), as described below:

- Blue** – entering the SCA having coordinated a descent with ATC; when no other aircraft are assigned to CATHY, the missed approach path is shown as a blue dashed line. AMM returned this information: **LATERAL entry, follow NONE, missed approach CATHY**
- Red** – having arrived by ATC instruction to the transition fix above the SCA at 4000ft with one other CATHY assignment, the AMM returned the following: **Vertical entry, follow BLUE, missed approach ANNIE**
- Purple** – departing the SCA via the departure procedure, and contacting ATC prior to DF
- Green** – released by ATC to depart (within a departure window); is holding short and using on-board tools to find an open slot in the arrival stream to take the runway and depart

Pilots that are given a “standby” sequence can track the number of aircraft in the SCA to estimate their delay as they continue to their clearance limit (which is the transition fix at an altitude above the SCA), and hold. When the pilot receives an AMM entry message with sequence and missed approach information, the pilot checks for the available holding altitude, and will request a descent from ATC. The pilot can then determine if a further descent is prudent by following the “lowest available altitude” procedure at the IAF, (clearing for traffic below is the pilot’s self-separation responsibility in the SCA). Pilots initiate their approach once adequate spacing behind the lead aircraft has been met. This adequate spacing is determined through either a generic rule-based spacing procedure that is safe for all combinations of aircraft performance, or by using an on-board self-spacing tool. The AMM reserves a holding slot for the assigned missed approaches. A pilot executing a missed approach would climb to the “lowest available altitude” at their assigned MAHF and would then be sent a new arrival sequence.

For SATS departures, pilots will file flight plans with a SATS departure procedure to a departure fix (DF, i.e., Figure 1 ELLEN or GINNY). Just as in today’s non-radar environment, pilots should expect a clearance void time and potentially a release time restriction as part of their IFR clearance. This affords seamless integration with today’s instrument flight operations. Within this ATC departure window, they will use on-board information and/or tools to deconflict themselves with landing traffic, e.g., ensure no arriving aircraft are within 5nm of the airport. The pilot would then depart and contact ATC according to the departure procedure before entering ATC controlled airspace.

## B. Roles and Responsibilities under the SATS HVO Concept

This section discusses roles and responsibilities from the controller’s perspective. Specific roles and responsibilities, refined into procedures for pilots and controllers, were evaluated in both airborne and ground-based simulations. These simulations included pilots and controllers, and are described in the next section.

For the application of SATS HVO procedures, the SCA must first be activated. This step is critical as it defines specific roles for both the pilot and controller with regards to required information exchange and procedures. For arrival aircraft, assuming an active SCA, the controller would initially provide normal services expected of an IFR aircraft landing at an airport in his/her sector. These services include providing advance approach control information (including verification that the SCA is active), which can be accomplished through verification that an Automatic Terminal Information Service (ATIS) or similar broadcast has been received by the pilot. Then, as traffic permits, the controller issues a direct routing to an IAF serving the approach to the SATS airport. When the aircraft is within 5 minutes of a 5 nautical mile ring around the IAF, onboard software allows the pilot to request an entry into the SCA from the AMM. This “5+5” request ring creates a “first come – first served” arrival sequence that compensates for different arrival speeds and winds aloft (faster aircraft have a larger circle while winds aloft shift the circle). Pilots are required to advise ATC immediately upon receipt of SCA entry approval so that the sequence of aircraft inbound to the IAF holding fix complements the order in which aircraft have received their entry approval. If a delay is required, the aircraft will be issued holding instructions at the IAF (s) above the SCA. ATC would manage the hold stack at the IAF, as in the non-SATS case. Upon receiving approval to enter the SCA, the pilot notifies ATC who then issues a clearance which releases the aircraft from ATC-controlled airspace. The transition of aircraft from ATC managed airspace into the SCA is a critical issue, as this is where the transfer of responsibility for separation takes place. When the aircraft enters the SCA, the pilot

is responsible for separation and this may well be the point at which all ATC services are terminated. An unresolved issue is how ATC is notified that the aircraft has safely landed and the flight plan can be closed. This notification is very important, since it could potentially involve alerting Search and Rescue services if the aircraft does not reach the airport.

For departures, again assuming a SATS environment, the process is very similar to today’s operations. The pilot files a flight plan, in this case from a SATS airport, and receives a pre-departure clearance. In advance of the anticipated departure time, a release from ATC will be requested. ATC will respond with a release (possibly including a void time), or a hold-for-release (HFR) with expected delay. Upon receipt of the release, the pilot departs as traffic permits, with the pilot providing his/her own separation from other departing and arrival traffic. The current concept requires that aircraft attempt contact with ATC prior to entering ATC controlled airspace. However, consideration needs to be given to requiring aircraft to contact ATC as soon as practicable after departure. This would allow controllers to radar identify aircraft as soon as possible and avoid any delay in providing radar services as aircraft exit the SCA. A more practical consideration is the release of protected airspace. As a departure is identified, any airspace that is protected for the SATS departure (and is governed by non-radar rules) can be released. A comparison of ATC functions for arrivals at uncontrolled airports is provided in Table 1 for today’s environment and for a SATS HVO environment.

**Table 1. Comparison of ATC functions in today’s operations verses SATS HVO operations**

<b>Baseline (today’s) Operation</b>	<b>SATS HVO Operation</b>
ATC: Advance Approach Info	ATC: Advance Approach Info
ATC: Vectors to FAC or routing to IAF*	ATC: Routing to IAF*
ATC: Sequence aircraft – controllers judgment	ATC: Sequence aircraft consistent with sequence provided by AMM
ATC: Issue Holding, if required	ATC: Issue Holding, if required
	ATC: Issue clearance which allows aircraft to exit ATC airspace
	ATC: Radar services terminated and issue approval for frequency change
ATC: Approach Clearance	
ATC: Radar services terminated and issue approval for frequency change	
ATC: Await IFR cancellation or confirmation of safe landing	

**C. Results of Current Research Activities**

The following two sections summarize the results of research conducted to date. The first section focuses on research that addresses the controller perspective, and the second section focuses on research that addresses airborne aspects of the SATS HVO concept.

**1. ATC Feasibility Assessments (controller-focused simulations)**

Three simulations were conducted to evaluate the feasibility of SATS HVO operations from a controller’s perspective at the William J. Hughes Technical Center. Assessments were conducted for SATS HVO in both the Center and Terminal airspace and operational environments. For reference, the simulations are referred to as Phase I (Terminal environment simulation), Phase II (Center environment simulation), and Phase III (Center environment simulation). The Phase III simulation was linked with pilot

stations at NASA's Langley Research Center, to provide simulated pilot and aircraft responses in real-time. Certified Professional Controllers from the facilities/sectors simulated were used in the feasibility assessment. Details of the simulations and results of these studies are found in (<sup>Ref. 3</sup>); a summary of these results follows.

Overall, both terminal and Center controllers viewed the SATS HVO concept favorably and felt that it was implementable. The major concerns expressed by the controllers included the amount of airspace required (as simulated) and the respective roles and responsibilities of the pilots and controllers. Across the three simulations, workload was assessed as being at or below that required for current procedures. Comments from subjects addressed airspace requirements, procedures, and communications and can be found in the referenced document.

## 2. SATS HVO Simulation and Flight Experiments (Airborne-focused simulations)

Determining pilot acceptability of HVO meant investigating research objectives through a piloted simulation and a subsequent flight experiment, to compare the SATS HVO Concept of Operations (CONOPS) to the one-in-one-out procedural control environment in use today. Research objectives for these experiments included obtaining answers to these questions:

- Can pilots safely and proficiently fly the airplane while performing SATS HVO procedures?
- Do pilots perceive that workload, while using HVO procedures and tools, is no greater than flying in today's system?

The analysis of Flight Technical Error (FTE) data complemented qualitative subject pilot assessments of workload, situation awareness, and HVO usability. Results from these studies indicated that all the evaluation pilots (low-time instrument-rated pilots) flew the HVO procedures safely and proficiently, with lower perceived workload, and higher perceived situation awareness when compared to today's procedures.

The HVO flight experiment validated pilot acceptability results for a subset of the HVO simulation scenarios. A common pool of pilots was used for both the simulation and flight experiments. Fifteen pilots flew the HVO Simulation Experiment, and 12 of those pilots flew the HVO Flight Experiment. This reduced training requirements for the HVO Flight Experiment and allowed pilots to progress logically from hand-flying a medium fidelity general aviation (GA) simulator to the Cirrus SR22 aircraft.

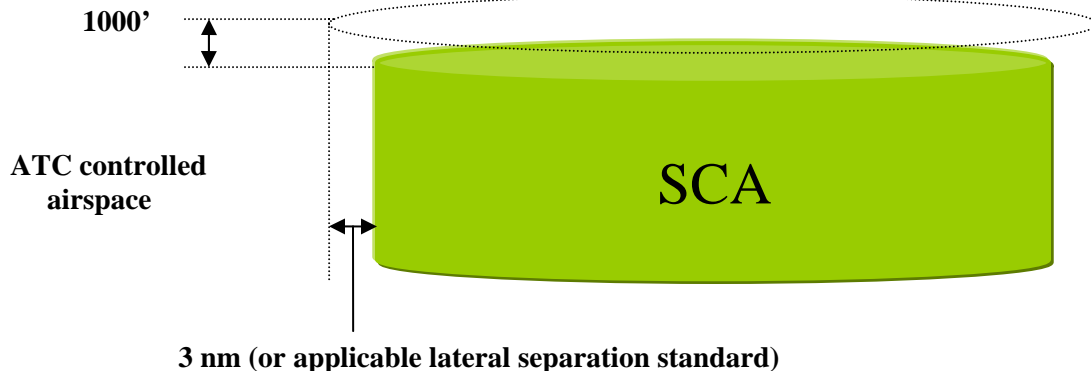
## **II. SATS HVO Implementation Issues – ATC perspective**

There are several issues of concern that have been identified when implementing SCA HVO in the current and envisioned ATC Systems. The majority of these issues that have been identified to date can be characterized into one of three general categories: Airspace, Procedures, and Communications (including phraseologies). These and other ATC-related issues are discussed in this section. To reiterate, none of the issues discussed are felt to be without solutions that can be implemented.

### A. Airspace

Central to the structure of the ATC System is the designation of different airspace classifications, as this determines the types of services that will be provided and the requirements for aircraft equipment and pilot training. Under the SATS HVO concept, airspace surrounding a SATS airport would be designated as SCA. The type of airspace designation appropriate for the SCA airspace needs to be determined. Will the SCA be considered controlled airspace because it will have defined dimensions, even though it will not have air traffic control service? Will there be no Minimum Safe Altitude Warning (MSAW) or Collision Avoidance (CA) alerts issued in this airspace? Will it be considered part of Class E airspace or will some other designation of this airspace be required?

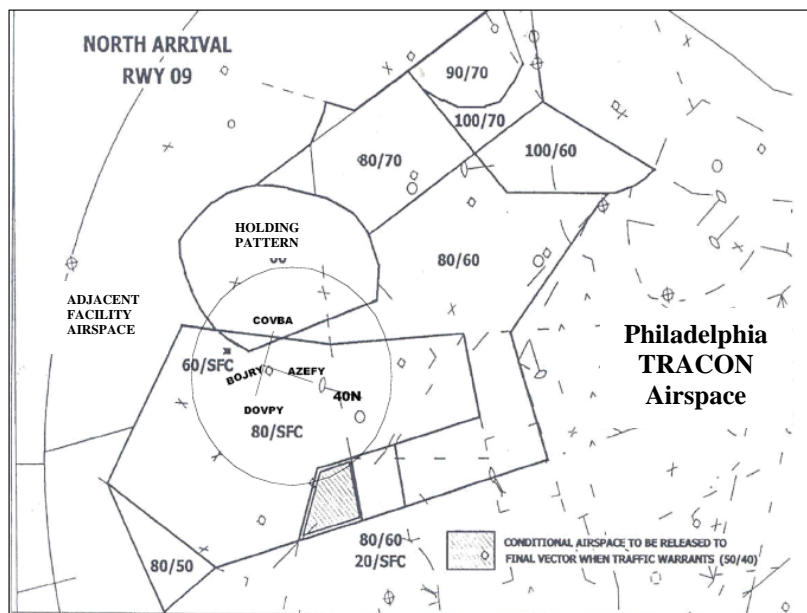
Under current rules, the SCA would be considered non-radar airspace because ATC does not exercise control in this airspace. This requires that ATC provide separation from the SCA for aircraft under their control, at a lateral distance or altitude equal to the separation required from non-radar airspace (Figure 2).



**Figure 2. Required separation from ATC controlled airspace and the SCA.**

The amount of airspace required for the SCA (containing the required holding pattern airspace) in addition to the protected area outside the SCA will potentially affect other air traffic operations. However, modifications to the generic dimensions (as defined in the CONOPS) of the SCA can mitigate this effect. An important consideration in the size and placement of an SCA are its effect on existing traffic flows, including arrival (approach) and departure paths, airways, Military Warning Areas, IFR routes, sector boundaries, facility boundaries as well as Class B, C, and D airspace boundaries.

It does appear that there would be significantly fewer challenges to implementing an SCA in Center airspace as compared to Terminal airspace. The basic reasons that TRACONs exist is that there is significant air traffic congestion at lower altitudes, thus justifying the need for a facility apart from the Center to provide approach control services. Due to this congestion and the relatively smaller size of the terminal sectors (compared to Center sectors), it would be inherently more difficult to introduce new airspace into this environment. Figure 3 shows a simulated SCA superimposed on the western part of Philadelphia TRACONs airspace.



**Figure 3. Simulated SCA implementation in Philadelphia TRACON airspace.**

This configuration was used for the terminal-area controller feasibility simulation study. For this study, the implementation of the SCA was generic and not optimized for the airspace surrounding the

simulated SATS airport. To illustrate the types of constraints encountered in implementing an SCA, the following points are made regarding the actual airspace constraints surrounding the simulated SCA. The circle (towards the middle left side of this figure) represents the SCA; recall that spacing (3 nm in this case) from the boundary of the SCA is required for separation of IFR traffic. The bold solid lines indicate the airspace “owned” by the North Arrival radar sector for the altitudes (x100) indicated in the various sections of the sector. The ceiling of the simulated SCA is 4000’. Considering these airspace dimensions airspace conflicts exists between the SCA/surrounding airspace to be protected and the holding pattern, another TRACON sector and an adjacent facility. The sorts of constraints and potential airspace conflicts that can be seen here are representative of some of the problems that could be encountered in implementing an SCA at other facilities.

As this example shows, in many cases compromises will have to be made in how airspace is subdivided to facilitate SATS HVO operations, while allowing ATC to maintain efficient operations for traffic under their control. The degree to which those ATC controlled operations are affected by a SATS SCA may determine the feasibility of including SATS operations at a given location.

## B. Procedures

A number of procedural issues necessary to support SATS HVO operations have been identified as needing to be addressed. These issues are listed and briefly discussed in this sub-section. A more thorough look at off-nominal procedures and operations is presented in reference 4.

*Activation/deactivation of the SCA:* A question that has not yet been definitively answered is who activates and deactivates the SCA; presumably, this would be an ATC function. The mechanics of how this would be accomplished is the subject of future investigations. Prior to activation of the SCA, all non-SATS IFR traffic would have to be clear of the area. The controller who owns the surrounding airspace would have the best information to make the determination of when this area is clear of traffic. It is also clear that transition to and from SATS HVO operations has to be non-disruptive to other air traffic operations and cannot create significant additional workload for the controller. Also to be addressed is a mechanism and procedures for transmitting the activation/deactivation of the SCA to other users of the surrounding airspace.

*Issuance of an EFC (Expect Further Clearance):* A fundamental question that has yet to be definitively answered is whether or not ATC should issue an EFC for aircraft issued holding instructions above the SCA that would be used in the event of lost communications. This concern stems from the fact that in the SATS HVO CONOPS, ATC exercises no control over aircraft that are in the SCA; hence there can be no assurance to the controller that the appropriate airspace through descent and approach can be protected. A potential solution is deactivation of the SCA when it is detected that an aircraft has lost voice communications.

*ATC services in the SCA:* There is a question as to whether any ATC services would be provided to aircraft in the SCA. Separation, under this concept would be the pilots responsibility, however, this does not necessarily preclude ATC providing other types of services. It should be noted, however, that during the evaluation at the FAA Technical Center, controllers indicated that they would feel uncomfortable providing any ATC services (e.g. safety alerts, air traffic advisories, etc.) in airspace for which they were not responsible. Further investigation to include simulations would be useful in reaching conclusions as to whether providing any ATC services in the SCA are feasible or practical.

*Monitoring to ensure safe arrival:* Currently, ATC monitors aircraft to ensure a safe arrival at the destination. If ATC is to continue this function, appropriate tools would have to be developed to support alerting if an aircraft landing at a SATS airport does not arrive safely.

## C. Communications

The number of radio transmissions required to support today’s operations versus SATS HVO operations is not significantly different. In terms of content, most communications required to support

SATS HVO operations exist with today's phraseologies<sup>(Ref 5)</sup>. One notable exception is the clearance required to transition aircraft from ATC controlled airspace into the SCA. The structure of this clearance is critical as it has to release aircraft from ATC airspace (and from the controller's responsibility for separation). However, the clearance can not provide a clearance altitude as the aircraft is descending into the SCA. The following candidate phraseology was developed and included as part of the controller feasibility study, and illustrates a request from a pilot (on a vertical entry) to leave IFR airspace, and the controller's response.

**Pilot:**

**“(Approach/Center), (A/C ID), Request descent out of IFR airspace.”**

**Controller:**

**“(A/C ID) Descend at your discretion, advise entering the SCA.”**

During the FAA Technical Center simulation, some of the subject controllers voiced concerns in the debriefings regarding the use of a discretionary descent clearance for this application, however, no specifics were given regarding the concerns or were any alternatives were suggested.

D. Other ATC-related issues

*Training for controllers:* Although there are some outstanding issues regarding the integration of SATS HVO operations in the ATC System, feedback from controllers in evaluations to date have clearly indicated that SATS HVO is implementable. Although SATS HVO is fundamentally different from current day operations, the concept was designed to require minimal training prior to application of this operation. This is supported by simulation results, where subject controllers were able to conduct the operations after about 2 hrs of training.

*Runway change at the SATS airport:* A runway change at a SATS airport with an active SCA poses several challenges. A sequence of activities required to facilitate a runway change are provided in Reference 4, however, the complete sequence of events remains to be identified. First, the AMM inhibits all new operations and ATC would not release any additional arrival traffic from the ATC airspace; all departure operations would be suspended. Arrival aircraft already inside the SCA on approach would either have to land or execute a missed approach. Eventually, all arrival aircraft in the SCA would have to transition to the IAFs serving the new runway, as would the aircraft under ATC control. The point at which a deactivation of the SCA occurs, and the SCA supporting the new runway is activated is a subject for further consideration. Following the transition of all aircraft to the IAFs serving the new runway and activation of the appropriate SATS airspace, SATS operations can resume.

*Effect of mixed equipage:* In the SATS HVO CONOPS, integration of mixed equipage (i.e. some aircraft are not equipped with the avionics required for SATS HVO) requires deactivation of the SCA. For an arriving non-SATS aircraft, this means that all SATS operations would have to be completed and no new ones initiated, until the non-SATS aircraft executes the instrument approach, lands, and advises ATC that he/she has landed safely. For a departure, SATS operations could resume only after the departing non-SATS aircraft is clear of the airspace that encompasses the SCA when it is activated.



*ATC Information and Display Requirements:* Specific information requirements to support the ATC side of the operation in implementing SATS HVO will be the subject of further investigations. Some of the information requirements envisioned are necessary for the controller to have, while others are not requirements but would be useful for planning purposes. A link between the AMM and ATC is assumed in the CONOPS, however, it has not been determined what specific pieces of information would be transferred or exchanged. At a minimum, ATC would need to know the status of the SCA, the active runway/approach, and the weather at the airport. Assuming an ATIS broadcast is provided, the controller would also need to know the current broadcast letter (or equivalent). For arrival aircraft, it may be useful for ATC to know the number of aircraft in the SCA (for planning) and when an aircraft executes a missed approach, as they may eventually want to re-enter the ATC airspace.

There is also a question as to whether the controller would want to continue displaying traffic after it has entered the SCA. Notification of runway changes would be essential as it could result in the suspension of operations in the SCA until the traffic flow could be reconfigured to accommodate the new active runway.

The display of other information that may be useful to the controller in facilitating SATS HVO, such as SCA status, has not yet been studied. Potential locations for displaying information pertaining to the SATS operations to the controller include the primary display, supplemental displays, and the aircraft data block.

### **III. Summary**

The SATS HVO Concept offers the promise of significantly improved efficiency at many of the nation's uncontrolled (and under-used) airports that will see greater use as air traffic demand in the future increases. Feasibility assessments from the controller's perspective clearly indicate that SATS HVO could be implemented into the ATC System; however there are issues that remain to be resolved before SATS HVO could be fully deployed at a facility. From the controller's perspective, these issues involve airspace requirements and design, pilot and controller procedures, controller training, and display of information to the controller. Based on the SATS team's consideration of the unresolved issues identified to date, reasonable solutions can or have been identified for all of them.

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<sup>2</sup> Abbott, T., Consiglio, M., Baxley, B., Williams, D., Jones, K., and Adams, C., "Small Aircraft Transportation System, Higher Volume Operations Concept", NASA/TP in preparation, September 2005

<sup>3</sup> Magyarits, S., Racine, N., Hadley, J., "Air Traffic Control Feasibility Assessment of Small Aircraft Transportation System (SATS) Higher Volume Operations (HVO)", DOT/FAA/CT-05/26, May 2005

<sup>4</sup> Baxley, B., Williams, D., Consiglio, M., Adams, C., and Abbott, T., "The SATS HVO Off-Nominal Operations", AIAA 2005-7461, September 2005

<sup>5</sup> Federal Aviation Administration, Air Traffic Control, FAA Order 7110.65P, February, 19, 2004