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Small Aircraft Transportation System Higher Volume Operations Concept

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October 2006

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Nomenclature

ADS-B: Automatic Dependent Surveillance - Broadcast

AGL: Above Ground Level

AMM: Airport Management Module

APDLC: Airport-Pilot Data Link Communications

ATC: Air Traffic Control

ATIS: Automatic Terminal Information Service

AWOS: Automated Weather Observing System

CD&A: Conflict Detection and Alerting

CD&R: Conflict Detection and Resolution

CDTI: Cockpit Display of Traffic Information

CPDLC: Controller Pilot Data Link Communications

CTAF: Common Traffic Advisory Frequency

D-ATIS: Digital ATIS

ETD: Expected Time of Departure

FAA: Federal Aviation Administration

FAF: Final Approach Fix

FN: Follow Notification

GPS: Global Positioning System

HVO: Higher Volume Operations

IAF: Initial Approach Fix

IFR: Instrument Flight Rules

IMC: Instrument Meteorological Conditions

LEN: Lateral Entry Notification

MAHF: Missed Approach Holding Fix

MAP: Missed Approach Point

MFD: Multi-Function Display

NAP: Nominal Approach Path

NAS: National Airspace System

PA: Pilot-Advisor

PFD: Primary Flight Display

RCO: Remote Communications Outlet

SATS: Small Aircraft Transportation System

SCA: Self-Controlled Area

TTA: Time To Approach

VEN: Vertical Entry Notification

VFR: Visual Flight Rules

VOR: Very High Frequency Omnidirectional Range

Abstract

This document defines the Small Aircraft Transportation System (SATS) Higher Volume Operations concept which is aimed at increasing the potential rate of flight operations during poor weather at our smaller airports. The general philosophy underlying this concept is the establishment of a newly defined area of flight operations called a Self-Controlled Area (SCA). During periods of poor weather, this block of airspace would be established around designated airports where procedural separation is currently employed, i.e. airports with no control tower and limited or no radar services. Aircraft flying enroute to a SATS airport would be on a standard clearance with Air Traffic Control 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. Departures would be handled in a similar fashion. This document also provides details for a number of off-nominal and emergency procedures which address situations that could be expected to occur in a future SCA. The details for this operational concept along with a description of candidate aircraft systems to support this concept are provided.

1.0 Introduction

The ability to conduct concurrent, multiple aircraft operations in poor weather at virtually any airport offers an important opportunity for a significant increase in the rate of flight operations, a major improvement in passenger convenience, and the potential to foster growth of operations at small airports. The Small Aircraft Transportation System, (SATS) Higher Volume Operations (HVO) concept (refs. 1-4) is designed to increase capacity at the smaller airports in the United States, airports where only procedural separation is currently employed by Air Traffic Control (ATC), i.e., airports with no tower and limited or no radar service. During periods of poor weather, a newly defined area of flight operations called a Self-Controlled Area (SCA) would be established around these SATS airports. Within the SCA, pilots would maintain their own separation from other aircraft using a combination of procedures and specialized tools, including localized surveillance data from other aircraft provided by an air-to-air data link. While pilots would self-separate within the SCA, a ground-based system located at the airport would assign arriving pilots their landing sequence based on aircraft position and missed approach requirements.

HVO relies on participating aircraft broadcasting critical flight information, such as position, heading, speed, and planned flight path information to other aircraft via data link. Flight information is received by all aircraft and displayed to each pilot. The pilot's awareness of this traffic, along with the HVO procedures and landing sequence information from the ground system, enables a distributed decision-making environment where the pilot maintains separation and spacing. The HVO concept does not depend on an ATC tower or designated approach times but rather allows the pilot to descend and then follow the preceding aircraft on the instrument approach. The pilot would use the onboard equipment to verify that the altitude and location to which his aircraft is descending is free of other traffic. Once adequate spacing behind the preceding aircraft is achieved and can be expected to be preserved throughout the approach, the pilot could begin the approach.

The HVO concept has the potential to work with any type of instrument approach (e.g., GPS or VOR), with the GPS-T approach being the basic approach type used throughout this paper. The generic HVO approach consists of dual Initial Approach Fixes (IAFs), approach paths, and a missed approach procedure to the Missed Approach Holding Fix (MAHF). Using two IAFs increases the number of aircraft ready to immediately start the approach, thereby increasing the approach rate at the airport. To minimize pilot and controller workload, the entire approach and missed approach operation is contained within the SCA. These features led to the most unique features of the HVO concept: the IAF and MAHF are at the same locations, with a unique missed approach procedure to each MAHF. To ensure the ability to self-separate even during off-nominal conditions, the maximum number of approach-to-landing aircraft allowed in the SCA is determined by the total number of IAFs and the associated holding pattern altitudes at those IAFs. For the generic GPS-T which has two IAFs, four arriving aircraft would be allowed within the SCA for landing; whether approaching the IAF, in holding at the IAF, on the approach, or on a missed approach.

Uncontrolled airports would only need to make relatively minimal infrastructure investments to increase their ability to sustain operations during periods of Instrument Meteorological Conditions (IMC). Airports would be expected to have a weather reporting capability (e.g., Automated Weather Observing System - AWOS) and would need to install an AMM, a ground-based ADS-B receiver, and have a data link capability.

For this operational concept to be viable, a link between the AMM and ATC would be required. This link would be necessary to enable ATC to terminate and subsequently re-enable HVO operations when necessary to accommodate procedural IFR operations. This link would also be necessary to efficiently enable HVO departure operations that would transition into traditional IFR airspace. Additionally, if controllers had access to the information relating to the number of aircraft operating in the SCA, this could help them better manage aircraft operating into the SCA airport. For example, if controllers knew that the SCA was not currently accepting aircraft (because the SCA was full), and that there would be a 20-minute delay at the airport, they could begin planning for that delay in advance. This information could then be provided to arriving aircraft by ATC or possibly broadcast on a system similar to Automatic Terminal Information Service (ATIS).

Failures and operational errors are also considered. In developing this paper, a major underlying assumption was that only pragmatic failures and operational errors (i.e., failures and errors that had a practical expectation for occurrence) would be addressed. Hence, while the list of off-nominal conditions presented is not complete, it does cover those cases that can reasonably be expected to be the majority of off-nominal occurrences. The major design goal for these off-nominal procedures was to minimize required changes to procedures and equipment relative to the normal HVO procedures while concurrently minimizing the level of system criticality (ref. 5). Also note that the inclusion of some equipment specifics in this document was required due to the interaction between equipment design and failures. Equipment design can be both a source of failure as well as a means to mitigate failures. Also, because equipment implementations can influence operational procedures, every attempt was made to minimize the impact of specific equipment implementations on the development of the overall operational concept.

Since the SATS project was focused on achieving a realistic, operationally deployable system for the 2010 timeframe, this concept emphasized ease of integration with the current and the planned near-term National Airspace System (NAS). It was further assumed that any additional ATC workload must be minimized and that enroute procedures would be as similar to today's system as possible. This concept is based on a distributed decision-making environment that would provide pilots with the necessary procedures, airborne systems, traffic awareness, and aircraft sequence information to enable safe

operations within the SCA while minimizing the requirements for the ground support tools. Since this is a distributed decision-making environment, much of the decision-making would be left with the pilot, as it is today with visual flight rules (VFR) operations into these non-towered airports. Finally, the overall philosophy was to emphasize simplicity and operational safety as major aspects in the design.

2.0 Design of the Self-Controlled Area (SCA)

A plan view graphic depicting a generic SCA is shown in figure 1. The SCA would be similar in concept to a Class E surface area and is similar to the proposal of reference 6. The waypoints could be existing waypoints for a generic Global Positioning System (GPS) T approach. In this concept, the outboard Initial Approach Fixes (IAFs) on the T (e.g., ANNIE and CATHY) would be used for all arrivals. These fixes would also be used as the missed approach holding fixes. (Note that alternative approach designs are discussed in Appendix A.) During low traffic conditions, arriving aircraft could fly directly to an IAF at the lowest appropriate IFR altitude and upon reaching the IAF, begin an approach operation. During periods of higher traffic conditions, the holding patterns in the SCA would be used to delay aircraft while they are waiting for appropriate aircraft-to-aircraft spacing prior to initiating the approach and landing. Arriving aircraft would enter at the top of the IAF holding pattern and then descend in 1000-foot increments as the altitude below becomes clear until reaching the initial approach altitude. At that time, the aircraft would self-separate along the approach path for landing. The profile view in figure 2 shows one of these arrival fixes and helps illustrate the holding pattern above the IAF. Note also that the shape of the SCA is similar to a Class C airspace design, but offset on the approach-side of the airport. Additionally, the shape of the SCA may also be tailored to fit the geometry of local airspace constraints. The IAFs on the opposite T (not shown in figure 1) could be used as the departure fixes. Due to the nominal location of these waypoints, and the requirement to protect the airspace around the holding patterns at these waypoints, the SCA would have a radius of approximately 10 nm. This would be a generic size and shape, established without any attempts to optimize the SCA size. Note that ATC would have to separate traffic operating outside the SCA by the appropriate minima from the SCA boundary to ensure separation. A discussion on this, as well as other considerations in implementing an SCA from the ATC perspective can be found in reference 7.

The holding patterns at the IAFs that are established within the SCA conformed to the current design standards for holding pattern dimensions. The holding patterns were used to absorb delays for aircraft waiting to begin an approach operation; this is consistent with current day use of holding patterns for delay absorption at capacity constrained airports. In the SCA, arriving aircraft would enter at the top of the holding pattern, or "stack", drop down in 1000-foot increments as the altitude below becomes clear, until reaching the bottom of the stack. At that time, the aircraft would self-separate along the approach path for landing. The purpose of the holding pattern in the SCA would be to delay aircraft while they are waiting for appropriate aircraft-to-aircraft spacing prior to initiating the approach and landing.
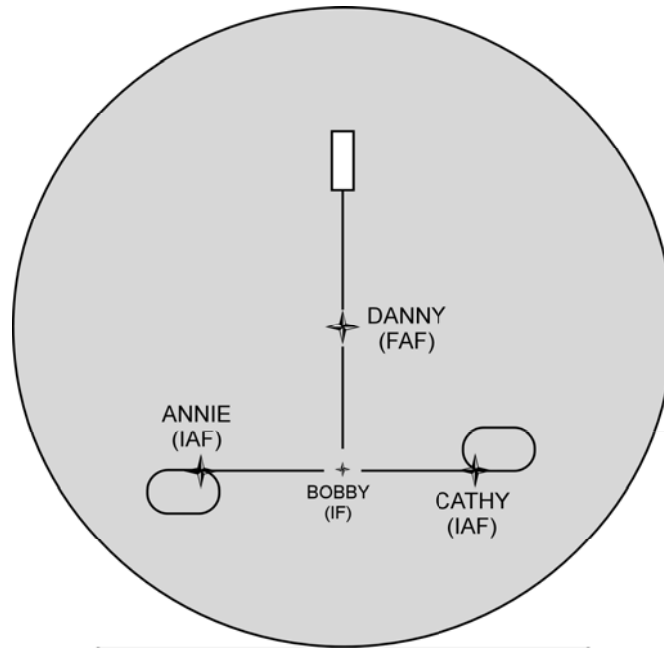
Figure 1. Plan view of the Self-Controlled Area
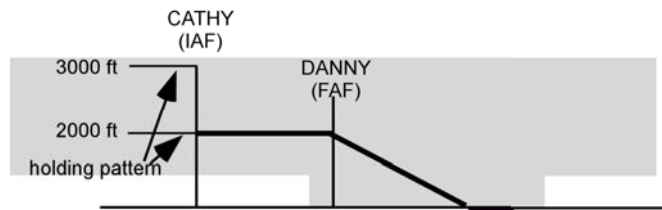
Figure 2. Profile view of the Self-Controlled Area

The SATS HVO concept would not depend on a control tower or designated approach times but rather would allow the pilot, using onboard equipment, to descend and then follow the preceding aircraft as designated by the AMM. The pilot would use the onboard equipment to verify that the altitude and location to which his aircraft was descending was free of other traffic. Pilots would then continue down the stack until arriving at the initial approach altitude (e.g., 2000 feet above ground level, AGL) at an IAF (e.g., CATHY). Once the appropriate approach spacing is obtained, the pilot would depart the IAF and continue down the approach. To contain this activity, the height of the SCA was set nominally at 3000 feet above the airport with the holding locations placed in the SCA at the outboard IAFs (e.g., ANNIE and CATHY) at 2000 and 3000 feet at both locations. The profile view in figure 2 shows one of these holding locations and helps visualize the stack above the IAF. Under certain conditions, VFR flight may be allowed at altitudes below 700 feet AGL. The SCA was sized so as to not penalize these enroute VFR operations except in the immediate vicinity of the airport. Again, the altitudes proposed for this airspace are nominal. Other altitudes and configurations could be established based on proper analysis and design constraints.

This concept further assumed that pilots would have the ability to contact ATC prior to entering and leaving the SCA. While communication is not required, it was assumed that airspace outside of the SCA would be under radar surveillance coverage by ATC. Although procedural separation could be used for aircraft entering and arriving into the SCA, if radar coverage was available adjacent to the SCA, transitions could be handled more efficiently. Outside of the SCA the airspace would be "owned" by ATC and ATC would be responsible for providing traditional separation services.

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Approach sequencing within the SCA would be managed by the AMM, which would rely on aircraft position information provided through a ground-based ADS-B receiver. Aircraft would be expected to contact the AMM via an Airport-Pilot Data Link Communications (APDLC) system and request landing sequence information. The AMM would then provide either a notification of which airplane the pilot would follow (if there were one in the sequence ahead of the pilot) or inform the pilot that he cannot enter the SCA along with a notification of the delay to expect before an entry would be granted. This sequence assignment process supports actions and decisions made by ATC in that the AMM sequences only those aircraft at the lowest altitude approaching an IAF, since ATC controls the order in which the aircraft arrive at the IAF. This process allows the controller the flexibility to resolve issues unknown to the AMM (e.g., crossing airways, weather, and aircraft holding).

To grant an entry, the AMM must also assure that there would be available missed approach airspace for each aircraft that is arriving in the SCA. Since it must be assumed that every approach may result in a missed approach and since there would not be an active controller involved in SCA operations (who could respond dynamically with unique missed approach instructions), each aircraft entering the SCA would be given its MAHF by the AMM as it enters the airspace. This technique would keep the ground-based automation relatively simple, and render an AMM failure less critical in the operational concept. However, it would mean that the total number of operations would be constrained by the number of unique missed approach locations that could exist within the SCA. For the SCA shown in figures 1 and 2, there are four missed approach holding options (two holding altitudes at each MAHF), therefore there are a total of four approach operations allowed at one time in this representation of an SCA. It is expected that this design would be modified for specific airport and airspace configurations. However, simple analysis has shown that designs with significantly more MAHFs may not significantly increase the number of allowable landing operations.

The objective of this operational concept is to enable increased numbers of operations in non-radar airspace (or airspace where procedural separation rules are being applied) at and around small non-towered airports in near all-weather conditions. For each element of the operational concept, a sample scenario is provided to describe that aspect of the operation. Other than the changes for SATS HVO operations outlined in this document, normal aircraft operating rules and procedures for non-towered facilities may not be explicitly portrayed in the scenarios, but are expected to apply.

3.0 SCA Operating Rules

As the definition of this concept evolved, it became obvious to the developers that several operational principles and constraints strongly affected the concept design, with the most significant being the requirement for missed approach airspace.

From the maximum of four operations (exclusive of departure operations) for the generic SCA in figures 1 and 2, a set of implementation and operating rules were developed. The normal SCA operating rules are as follows:

- No more than four concurrent arrival operations are allowed in the SCA.

- Entries may not result in the assignment of more than two aircraft to a specific fix, with the assignment as either an IAF or a MAHF.

- Simultaneous entries are not allowed at an IAF.

- Entries are allowed at an IAF only if no aircraft is on the approach with that fix assigned as their MAHF.

- Entries are only allowed at altitudes at or below the lowest IFR altitude above the vertical limit of the SCA (fig. 3).

- Vertical entries (descending into the SCA while in the arrival holding pattern) are only allowed at the IAFs from the lowest IFR altitude above the SCA.

- Upon entering the SCA at an IAF, aircraft are to go to the lowest available altitude and then continue to descend as altitudes below them become available.

- Alternating MAHFs are given to sequential aircraft (e.g., the first aircraft is given ANNIE, the second aircraft is given CATHY, the third aircraft is given ANNIE, etc.). Note that for operational efficiency reasons, if there were no other landing aircraft (i.e., aircraft with entry notifications) in the SCA, the first arriving aircraft would be assigned a "same-side" MAHF (e.g., if the arrival fix is CATHY, the MAHF will be CATHY). An example approach chart with AZBEJ as the MAHF (equivalent to CATHY in the generic figures) is given in figure 4.

- When proceeding to a holding fix on a missed approach, aircraft are to climb to the lowest available altitude (e.g., the first aircraft heading to ANNIE climbs to 2000 feet, the next aircraft going to ANNIE climbs to 3000 feet).

- Aircraft operating in the SCA must be able to climb at 300 feet per mile (required for obtaining the required vertical separation at a MAHF if the lower altitude is occupied).
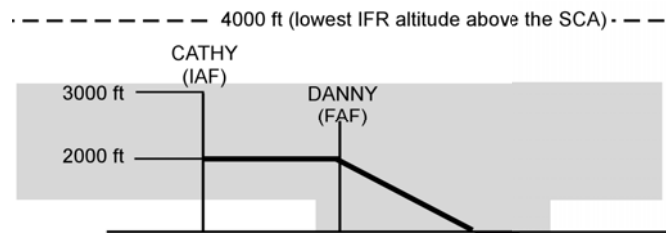
Figure 3. Example of the lowest IFR altitude (AGL) above the SCA.

MELFA, VIRGINIA

SATS RNAV (GPS) RWY 3 AZBEJ

MELFA/ACCOMACK COUNTY (MFV)

APP CRS 034°	Rwy ldg 4999 TDZE 47 Apt Elev 47

SATS Equipped Only GPS or RNP-0.3 required DME/DME RNP .3 NA	Missed Approach: Climbing right turn to lowest available (2000 or 3000) via LNAV path to AZBEJ and hold.

AWOS-3 118.175	NORFOLK APP CON 126.05	UNICOM 122.8 (CTAF)

SATS Self Controlled Area

331 ±

515

264

JAGNO (MAF and Threshold)

349

MELFA (FAF) 374

(IAF) UHYEZ

124°

304°

2000 124° (5)

1500 034° (5)

(IF) UCGEL

2000 304° (5)

124°

304°

(IAF) AZBEJ

ELEV 47

127 ±

5004 X 100

143

TDZE 47

034° TO RWY 3

136 ±

REIL Rwys 3 and 21
MIRL Rwy 3-21

2000 AZBEJ

UCGEL
3000
2000

034°

MELFA
1500
3.00°
TCH 40

JAGNO

5 NM   4.5 NM

CATEGORY	A	B	C	D
LNAV MDA	440-1 393 (400-1)			440-1 1/4 393 (400-1 1/4)
CIRCLING	NA			

MELFA, VIRGINIA

SATS RNAV (GPS) RWY 3 AZBEJ

MELFA/ACCOMACK COUNTY (MFV)

Figure 4. Example of an approach chart.

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4.0 Aircraft Equipment

4.1   Conflict Detection and Alerting

A design decision was made that neither conflict detection and alerting (CD&A) nor conflict detection and resolution (CD&R) would be required as a primary means for aircraft separation in conducting HVO. That is, the HVO procedures, with the supporting AMM design and relatively simple flight displays, would provide the primary means for aircraft-to-aircraft separation within the SATS SCA. It was assumed, however, that either CD&A or CD&R would be required as a secondary means for operational safety. Given this, the inherent nature of off-nominal situations will probably require an onboard conflict detection system to obtain an operationally viable level of safety. A description of an HVO CD&A concept is provided in Appendix B with further details provided in references 8-9.

4.2   Prototype Aircraft Multi-Function Display

The functionality and display formats of a modern multi-function display (MFD), similar to a current-generation GPS moving map display, were assumed as the implementation basis for the SATS HVO concept. A basic map-page layout for this MFD is shown in figure 5. Major functions and display items assumed for the map portion of the MFD are:

- A track-up, moving map display that includes both geographic and navigation information.

- Aircraft-centered and aircraft-offset formats.

- Adjustable map range scales.

- Programmable bezel buttons.

- Feature-select knobs.

Figure 5. MFD map layout.

In addition to the navigation map information, the MFD would provide traffic information (ref. 10), HVO-specific alerting information, and APDLC messages. APDLC messages could provide AMM messages as well as general airport information, such as Digital Automatic Terminal Information Service (D-ATIS). Note that APDLC is a two-way, addressed data link that would function in a manner similar to a Controller-Pilot Data Link Communication (CPDLC, ref. 11) system. The MFD would also include both an AMM-procedure display window and a pilot procedure tool window (ref. 12), both unique to the HVO concept. An example of the AMM-procedure display window is provided in section 5.2. The pilot procedure tool, called the Pilot-Advisor (PA), would provide an automated HVO-specific checklist to the pilot relative to the current state of the aircraft and other surrounding traffic. Effectively, the PA would provide prompts in the PA window to the pilot regarding the next appropriate procedural step for the current HVO procedure (e.g., a message stating that it is clear to descend during an approach operation). The PA window would only display one message at a time, with that message being the oldest message with the highest priority. Table 1 lists the proposed messages, with priority level 1 as a higher priority than priority level 0. For example, the "Monitor Path" (blue, priority level 1) takes precedence and would overwrite the "OPEN: 2000" message (black, priority 0). The message text color would be consistent with alerting standards (ref. 13). The prototype messages for the PA information, displayed in the PA window on the MFD, are provided in table 1. The SATS HVO concept does not require the use of a PA, although preliminary tests with subject pilots found it to be highly desirable (ref. 12). The use of these messages will be explained in subsequent sections.

Alerting information, provided in an alert window on the MFD map, along with any appropriate audio cues, would also be provided via the MFD. Alerting information would include the following:

- The availability of any new broadcast message (e.g., AWOS, D-ATIS, or AMM broadcast data).

- The reception of any new AMM instruction addressed to the aircraft (e.g., entry notification).

- A new PA message.

- Traffic conflict messages.

This MFD implementation, along with the PA tool, is but one possible means for providing an airborne capability to support the HVO concept.

Table 1. Pilot-Advisor (PA) Messages

Message definition	Example message	Priority level
The pilot is entering the SCA without an entry notification	NO SEQUENCE EXIT SCA	1
The pilot is entering the SCA at the wrong IAF.	WRONG IAF	1
"Open altitude" informs the pilot of the next altitude that is required for the current procedure and indicate that no other aircraft is occupying that altitude. This message example informs the pilot that the 3000 ft altitude slot is open (available).	OPEN: 3000	0
The pilot has climbed or descended beyond the open (available) altitude. This message would be displayed on the second line of the PA window as a modifier to the instruction displayed on the first line.	OPEN: 3000 MONITOR ALT	1
If an operation is pending but has not occurred after a predetermined time due to an unexpected delay by the pilot, a "proceed now" prompt will be added to the PA message. This message will also be associated with an alert.	OPEN: 2000 PROCEED NOW	1
Time-To-Approach (TTA) defines when the aircraft may leave the IAF with the appropriate spacing behind the aircraft it will be following. The example is 1 minute, 32 seconds before approach initiation.	TTA: 1:32	0
This message shows the pilot that the approach may be initiated.	OPEN: APPR	0
This message shows that the separation distance from the pilot's aircraft to the preceding approach aircraft is below the nominal value (for either an approach or a departure) and that the pilot should reduce speed.	TOO CLOSE REDUCE SPD	1
The pilot is flying faster than the nominal approach speed.	TOO FAST CHECK SPEED	1
The pilot is flying slower than the nominal approach speed. This message is inhibited if a "too close" message has been issued.	TOO SLOW CHECK SPEED	1
The pilot is flying off of the approach path.	MONITOR PATH	1
The pilot is the second aircraft conducting a missed approach to a common MAHF, and he is overtaking the preceding missed approach aircraft. An expedited climb to 3000 ft is required in this example; this information would be shown on the second line of the message window.	OPEN: 3000 CLIMB NOW	1
The pilot is going to the wrong MAHF.	WRONG MAHF	1
This message shows that a departure may be initiated. It is displayed when the pilot is ready for takeoff and there is sufficient separation between both arriving and departing aircraft for an HVO departure operation to be performed.	OPEN: DEPART	0
The pilot is flying the wrong departure procedure.	WRONG DP	1

5.0 Normal Procedures

5.1   Preliminary Data Exchange while in Enroute ATC Airspace

No unique SATS provisions were anticipated for filing and following flight plans, so the pilot would simply be required to file a traditional IFR flight plan to the SATS destination airport. The aircraft special equipment designator on the flight plan would identify the aircraft to ATC as SATS capable. The final fix in the route-of-flight section of the flight plan would be a SATS transition fix, which would be an IAF for a SATS instrument approach at the destination SATS airport.

Note that the AMM would be broadcasting the total number of aircraft that are sequenced for landing within the SCA and are requesting entry from outside the SCA. This information could be used by the pilot in considering alternate airport options.
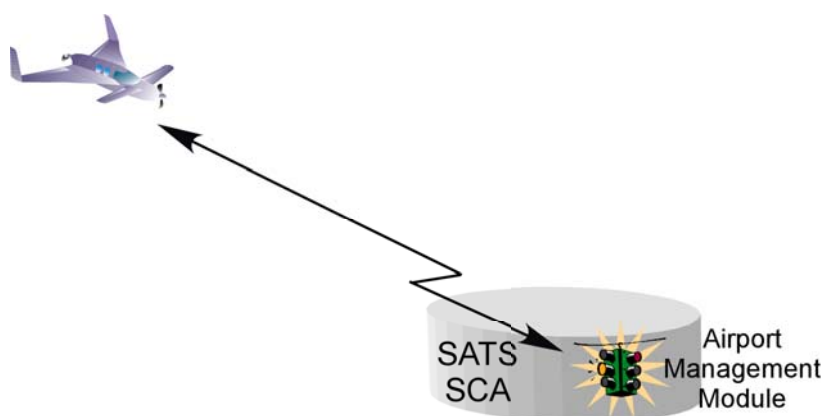
Figure 6. Preliminary data exchange

Prior to reaching the transition fix, the pilot would request a landing sequence assignment from the AMM (fig. 6). Note that the aircraft would be broadcasting, via APDLC, the planned IAF. (Also note that while the SCA is depicted as a single cylinder in figure 6, it is actually a two-tiered volume, as depicted in figure 2.) To be eligible to request a landing sequence, the aircraft must be within 5 minutes of a 5 nm radius around the planned IAF, with the time based on the aircraft's closure rate with that fix. The AMM would then determine a sequence number for the arriving aircraft relative to other aircraft already in the SCA. If an arrival opening were available, the AMM would issue an entry notification. If the SCA were "full," the AMM would issue a "STANDBY" notification. The scenario sequence for this operation is shown in table 2. This table portrays the chronological order in which airplane or pilot actions, ATC actions, and AMM action occur for a typical scenario defining this phase of the SATS operation. Also note that a simplified flow chart of a normal HVO arrival operation is provided in Appendix C.

Table 2. Preliminary Data Exchange.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
On a standard IFR flight plan to the SATS airport. The current clearance is to "ANNIE" at 4000 ft. Obtains the ATIS information for the airport. Requests an approach sequence from the AMM. Aircraft broadcasts planned IAF.		Broadcasts number of approach-requesting aircraft. A sequence number is computed.

5.2   Lateral Transition and Entry into SATS HVO Airspace

The intent of the lateral entry would be to allow, during periods of low demand, a SATS aircraft to directly transition into the SCA at an altitude below the ceiling of the SCA. This direct transition would potentially eliminate any holding at the IAF. Since the SCA demand level may not be known until the aircraft reaches the vicinity of the SCA, a lateral entry into the SCA should not be flight-planned or expected by the SATS pilot.

To accommodate a lateral entry capability, the SCA was divided into three areas: one departure area (in figure 7, this is the top area of the SCA, shown in white) and two arrival areas (in figure 8, the yellow and blue areas). To determine if a lateral entry would be permissible, the AMM would use the following special rules:

- If any other aircraft was at the IAF or was assigned to the IAF (e.g., for a missed approach), a Lateral Entry Notification (LEN) would not be issued.

- If the arriving aircraft was on the departure-side of the SCA (in figure 7, this is the top area of the SCA, shown in white), a LEN would not be issued.

- If the arriving aircraft would transition more than one arrival area, a LEN would not be issued.

- If the entry would result in the assignment of more than 2 aircraft to a fix as either an IAF or as a MAHF, a LEN would not be issued.

- If none of the above exceptions applied, the AMM would issue a LEN.
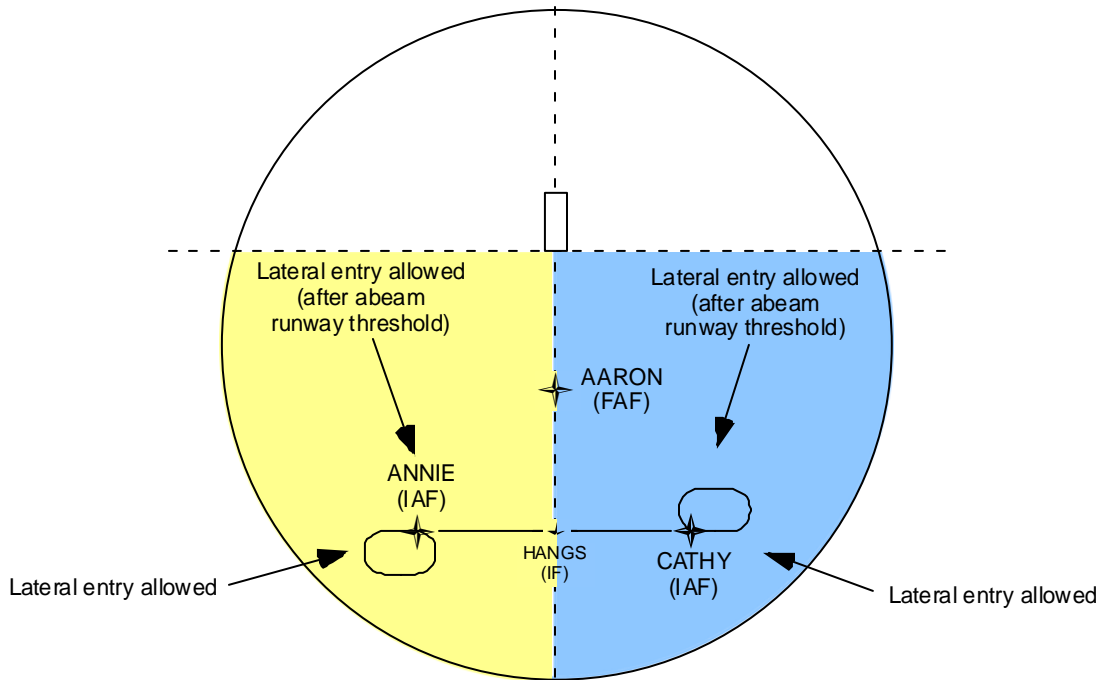
Figure 7. Lateral entry areas.
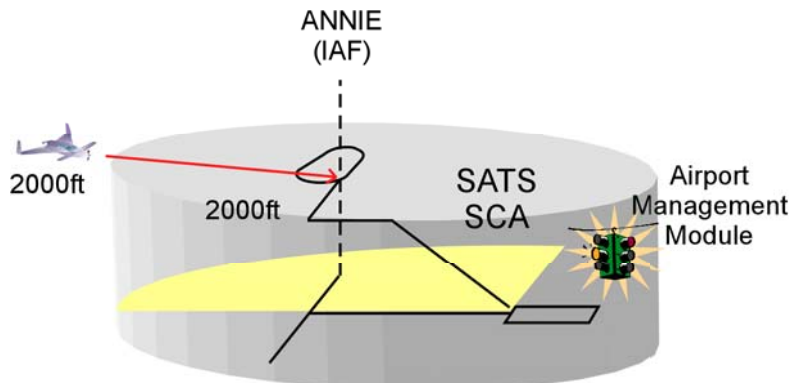
Figure 8. Lateral entry into the SCA.

If a lateral entry was not possible (before the aircraft reached the vicinity of the IAF), the AMM would issue a STANDBY message. Under this situation, the SATS pilot should expect a vertical entry into the SCA.

If the arriving aircraft was provided a LEN, a follow notification (FN) and missed-approach fix assignment would also be issued from the AMM. The SATS pilot would then request a clearance from ATC to depart ATC controlled airspace (fig. 8). Note that a descent to the IAF approach altitude may also begin at this time assuming that all other constraints were met (e.g., approval from ATC while in ATC airspace and maintaining at or above obstruction clearance altitudes). Once at the IAF, the SATS pilot would descend at the IAF to the lowest available altitude at that fix per the SATS procedure. The scenario sequence for this operation is shown in table 3.

Table 3. Lateral Transition from Enroute ATC Airspace.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
On a standard IFR flight plan to the SATS IAF, "ANNIE," at 4000 ft. Aircraft sends planned IAF and landing request. Confirms that there are no other aircraft at ANNIE. Requests clearance to depart ATC controlled airspace, transition prior to ANNIE at 2000 ft. Transitions into the SCA at 2000 ft and continues direct routing to ANNIE.	 Clears aircraft to depart ATC airspace.	 Determines that a lateral entry is permissible at ANNIE. Prior to ANNIE, transmits LEN, FN, and MAHF information.

As described in section 4.2, an AMM-procedure display window would be provided on the MFD (fig. 5). For an approach operation, this window would provide a sequenced list of actions that would be part of this operation. In the example of figure 9, the window shows that the pilot is to perform a lateral entry at ANNIE, then follow the aircraft with the identifier of N12345. If a missed approach was required, the MAHF would be CATHY. The items would be automatically removed from this list as they are performed.

```
ENTRY: LAT
KMFV-IAF: ANNIE
FOLLOW: N12345
GPS3-MAHF: CATHY
```
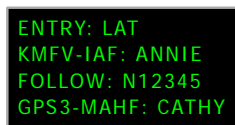
Figure 9. Example of the AMM-procedure window on the MFD.

5.3   Vertical Transition from Enroute ATC Airspace to the SATS SCA Boundary

For a vertical transition into the SCA, the AMM would issue a vertical entry notification (VEN) and a FN to the SATS aircraft. The FN pairs the SATS aircraft with the aircraft it would follow. If there was no preceding aircraft to follow, the FN would indicate "NONE." The SATS pilot could then request a descent from ATC.

If an approach sequence was not currently available, the AMM would continue to issue a STANDBY message. The pilot could then use the AMM broadcast of the number of SCA arrival operations to estimate the landing delay and advise ATC of the need for a hold. The scenario sequence for this operation is shown in table 4.

All of the following rules must be met prior to the AMM permitting a vertical entry into the SCA:

- There are fewer than two aircraft at the fix (as an IAF) or assigned to it (as a MAHF).

- There are no other entries in progress at the specific fix.

- No other aircraft that are assigned to that fix as a MAHF are on the approach.

- The entry will not result in the assignment of more than two aircraft to the fix as either an IAF or as a MAHF.

Table 4. Vertical Transition from Enroute ATC Airspace.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Contacts ATC and advises of a 20 minute delay (estimated by the pilot based on the number of preceding aircraft)[1].	ATC issues a holding instruction to the SATS pilot: "*N1234S, hold west of ANNIE as published, maintain 4000 feet. Advise when ready to enter the SCA.*" Note that ANNIE has a depicted, enroute holding pattern[1].	Broadcasts that there are 6 preceding traffic[1]. Once SCA airspace is available, transmits a VEN, a FN, and MAHF information.

[1] Only required for a delay. A loss of voice communication capability is accomplished via a SATS procedure (section 6.5.7) in lieu of an expect further clearance time from ATC.

5.4 Vertical Entry into SATS HVO Airspace

Once the airspace below the SCA transition altitude becomes available and the aircraft is at the lowest IFR altitude above the SCA, the AMM would issue a VEN and a FN to the aircraft. This airspace availability would occur as the preceding aircraft (at the same IAF) also descends or begins the approach (fig. 10). The SATS pilot would then confirm, via the SATS MFD, that he was cleared to descend into the SCA. Note that the PA would provide an "OPEN: 3000" message (see table 1). The SATS pilot would then request a clearance from ATC to descend. Once cleared by ATC, the SATS pilot would descend at the IAF to the lowest available altitude at that fix per the SATS procedure. The scenario sequence for this operation is shown in table 5.
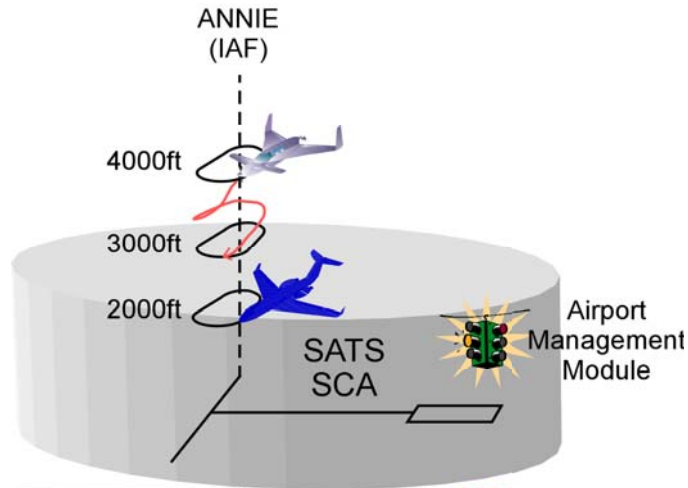
Figure 10. Vertical entry into the SCA at the transition fix.

Table 5. Vertical Entry into SATS HVO Airspace.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
		Determines that at least one slot is available, that one slot is open at the IAF, and that the aircraft is at the lowest IFR altitude above the SCA. Transmits IAF, VEN, FN, and MAHF information.
Confirms open slot at 3000ft. Requests descent. Descends into SCA, holding at the IAF at 3000ft[1]. Descends to the lowest possible altitude at the IAF.	Clears aircraft for descent and departure from ATC airspace.	

[1] only required if there is an aircraft at the lower altitude at the IAF.

5.5 Continued Descent at the Initial Approach Fix

As the airspace becomes available at lower levels at the IAF, the SATS pilot would descend to that level. This availability would occur as the preceding aircraft also descends or begins the approach (fig. 11). Note that the pilot would receive an "OPEN: 2000" from the PA. The scenario sequence for this operation is shown in table 6.
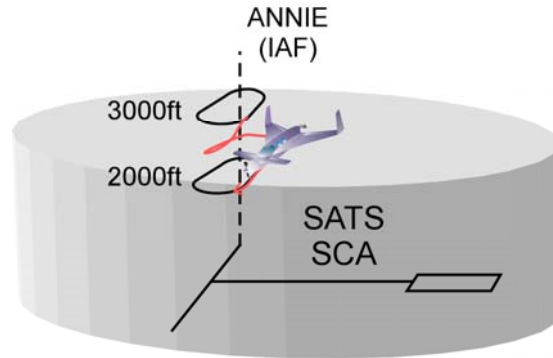
Figure 11. Descending at the initial approach fix.

Table 6. Continued Descent at the Initial Approach Fix.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Determines that a lower level is available at the IAF. Descends to 2000ft.		

5.6 Initiating the Approach

Upon receiving the FN, the SATS pilot must determine if the preceding aircraft is spaced sufficiently far ahead, based on a self-spacing interval (discussed later in this section), such that he could begin his own approach. Note that the leading aircraft could be at the opposite IAF (e.g., CATHY vs. ANNIE). In this instance, the pilot could be assisted by the PA with an approach spacing message. Prior to sufficient spacing, the PA would provide a time-to-approach message (e.g., "TTA: 1:32," see table 1) to indicate that the pilot must wait for 1 minute and 32 seconds before initiating the approach. Once sufficient spacing exists, the PA would provide an "OPEN: APPR" messaging denoting that the approach is "open."

All SATS aircraft should be able to self-space using a baseline procedure. This baseline procedure would be used to delay at the IAF until the spacing from the lead aircraft met the spacing criteria. SATS pilots desiring greater efficiency could be helped through onboard tools (i.e., a Pilot Advisor system) that would enable the pilot to dynamically manage spacing. In this latter case, this determination would be based on his aircraft's planned performance, the actual and planned performance for the preceding aircraft, the approach geometry, wind conditions, and other factors. Once the spacing criterion had been met, the pilot would leave the holding pattern and initiate the approach (fig. 12). The scenario sequence for this operation is shown in table 7.
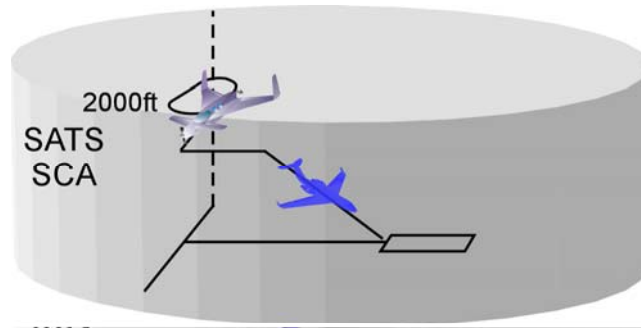
Figure 12. Initiating the approach.

Three proposals have been developed for approach initiation and approach spacing. The order of these proposals is from low efficiency and low complexity to high efficiency and high complexity. Note that low efficiency relates to a high "error budget" in the design. That is, if only low fidelity data or little processing were required, a large error allowance would be required for operational acceptability. Also note that these procedures would probably be unique or customized for each approach. The three proposals are:

  - Simple charted procedure: For example, when the leading aircraft was 6 nm from the runway (as would be shown on the SATS approach display), the SATS pilot could start his approach.

  - Pair-wise initiation: A somewhat more efficient but more complex alternative to this concept would be an approach speed based technique, where the pair-wise differences in the planned approach speeds [both before and after the final approach fix (FAF) for both aircraft] would be used in the determination of the aircraft separation prior of the initiation of the approach. This is the technique used in the PA example.

  - Active spacing: The most sophisticated and efficient technique would begin with the previously described pair-wise means for initiating the approach. It would then use continuous, dynamic speed guidance for active spacing relative to the leading aircraft.

Table 7. Initiating the Approach.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Determines if the preceding aircraft is sufficiently far ahead such that it can begin its own approach. If the preceding aircraft is sufficiently far ahead, begins the approach.		

5.7   Flying the Approach

No unique SATS HVO requirements were identified for navigation and guidance along the front-side (i.e., prior to the missed approach point) of the approach (fig.13). The scenario sequence for this operation is shown in table 8.

During the approach, the aircraft would continuously monitor, via an onboard alerting capability, the relative spacing between it and the preceding aircraft. (For the PA example, the PA function that computes the spacing interval required to initiate the approach could also be used to provide alerting. Simple calculations within the PA, using aircraft speeds, the approach geometry, and a safety buffer, would probably be sufficient for this application.) If the following aircraft were predicted to get closer than the nominal spacing, then an alert would be given to the following aircraft to reduce its approach speed. If the following aircraft were predicted to get closer than the safety minima to the aircraft that it is following, then a procedure (section 6.4.2) would be used to mitigate this situation. Also note that while the missed approach segment is part of the approach, it is discussed in a subsequent section.
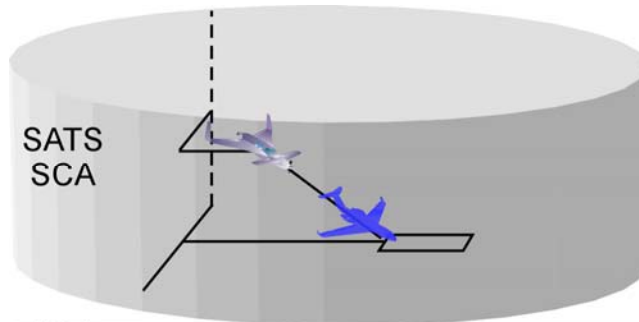
Figure 13. Flying the approach.

Table 8. Flying the Approach.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Monitoring spacing during the approach[1].		
Reduces speed if getting closer than nominal.		
Performs loss-of-spacing procedure if spacing is too close.		
Visually acquires approach end of runway (Category I conditions).		

[1] may have a Pilot Advisor or dynamic speed guidance.

5.8   Landing

Because the landing operation (fig. 14) would occur in visual conditions, there are no unique SATS HVO system requirements for this phase of flight. If the aircraft cannot land, then the missed approach procedure would be flown.
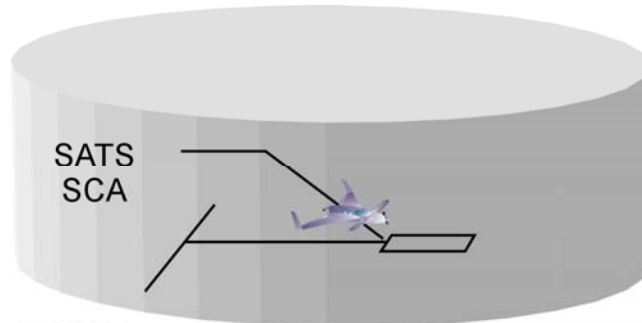
Figure 14. Landing.

5.9   Initiating a Missed Approach

The AMM would not assign two consecutive aircraft to the same MAHF. The MAHFs would nominally be the two IAFs on the GPS T (e.g., ANNIE and CATHY, in figure 15). Aircraft on a missed approach would go to the lowest available holding altitude (fig. 16), simplifying the transition for another approach. The scenario sequence for this operation is shown in table 9.

If a missed approach was required, the SATS aircraft, as in normal IFR procedures, could begin a climb to the missed approach altitude at any point along the instrument approach path prior to the missed approach point (MAP). It is expected that the MFD would provide the MAHF information to the pilot. This information should reduce the possibility of the pilot turning toward the wrong MAHF. As in normal IFR procedures, the turn to the MAHF may not begin until the aircraft passes the missed approach point. Once the aircraft initiates its missed approach, that action is broadcast by the aircraft, and the aircraft would be automatically re-sequenced for another approach. The operation to depart the SCA from the missed approach is defined in a subsequent section.
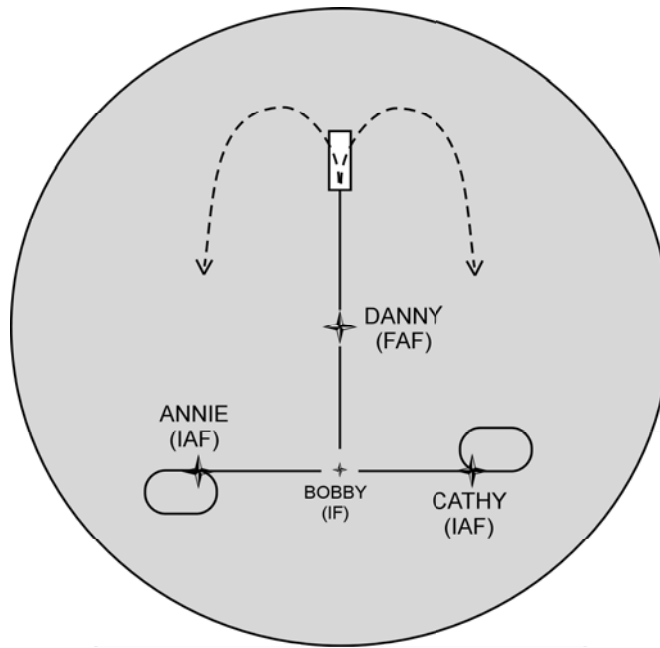
Figure 15. Plan view of missed approach.
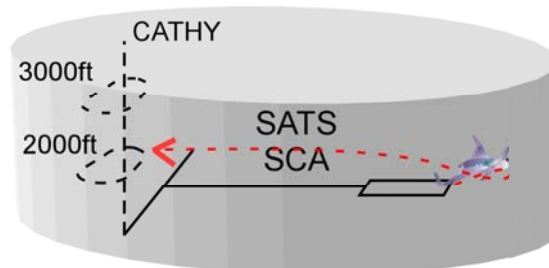
Figure 16. Missed approach.

Table 9. Initiating a Missed Approach.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Initiates missed approach procedure. Aircraft broadcasts missed approach initiation.		
Determines the lowest available altitude at the MAHF.		
Climbs to the lowest available altitude at the MAHF.		
		Transmits new FN and MAHF information.
Holds at the MAHF.		

5.10 Initiating a Departure

   A pilot who wants to depart the SATS airport would file a normal IFR flight plan that would include a designated SCA departure procedure, also noting that a traditional flight plan would also include an expected time of departure (ETD). The departure procedure would include a minimum of one departure fix outside of the SCA. A generic SATS airport would have two departure fixes which would typically be the opposite-direction IAFs for the runway (fig. 17). In a manner similar to current operations at remote airports, approximately 30 minutes prior to the planned departure time, the pilot would contact ATC or flight service to obtain a clearance. With the receipt of the clearance, the pilot would also be informed of any expected delay that would affect the ETD. Note that the SATS pilot may only receive a short range clearance (ref. 14) that would end at the last fix of the departure procedure (which is outside of the SCA). A simplified flow chart of a normal HVO departure operation is provided in Appendix C.
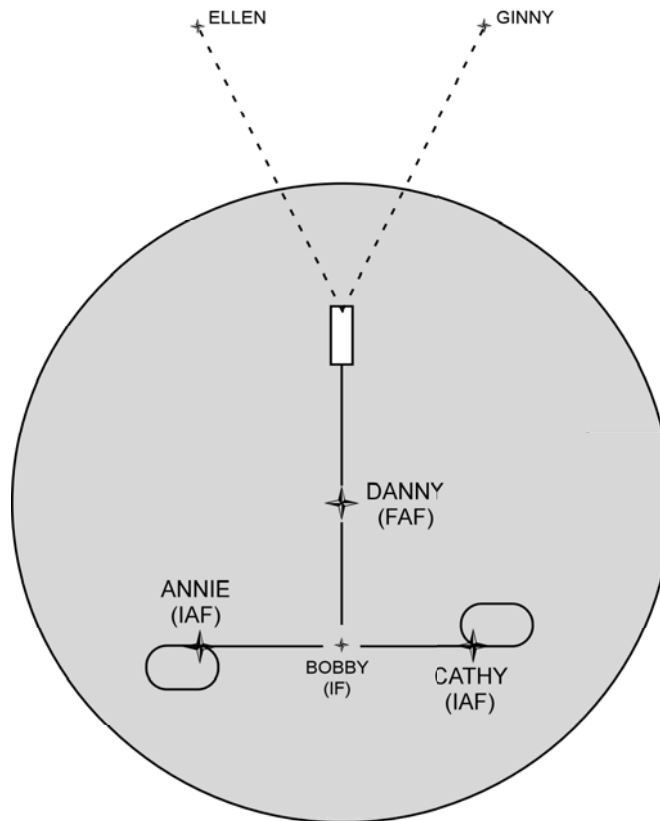
Figure 17. Plan view of generic SATS airport depicting two departure fixes.

   Prior to the ETD and including any additional delay that was advised by ATC, the SATS pilot would have completed all preflight checks and be ready to depart the SATS airport. Immediately prior to the ETD, the SATS pilot would monitor the approach stream (i.e., the aircraft that are on the approach) for a potential departure slot. The determination of a departure slot could be done in a manner similar to the options used for initiating an approach (i.e., from a simple Cockpit Display of Traffic Information - CDTI based procedure through an advanced automation tool). Once a departure slot had been identified, the SATS pilot would contact ATC through a Remote Transmitter Receiver, Remote Communications Outlet (RCO), CPDLC, or some other means to obtain a departure release. In a normal situation, it would be expected that ATC would immediately release the aircraft for entry into traditional ATC controlled airspace. This release would include a void time.

The SATS pilot would then confirm, via an automated check with the AMM, that the ADS-B output and APDLC were operating correctly. The SATS pilot would then confirm, or delay as appropriate to ensure, that a safe departure was possible, taxi on to the runway, and depart (fig. 18). The scenario sequence for this operation is shown in table 10.
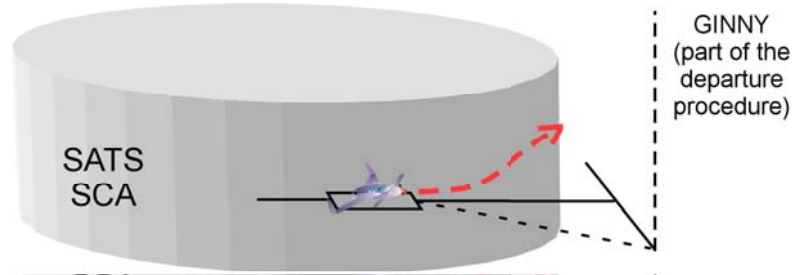
Figure 18. Initiating a departure.

If ATC was unable to accept the departure aircraft at the time of the pilot's request, ATC would normally provide an expected delay time. At the end of that expected delay time, the SATS pilot, having repeated the last several departure steps, would again contact ATC for a departure release.

Table 10. Initiating a Departure.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Files a standard IFR flight plan that includes the SCA departure procedure.		
30 minutes prior to the planned departure time, contacts ATC (direct or via Flight Service) for the clearance.		
	Provides IFR clearance and any expected departure delay time.	
Immediately prior to ETD, resolves a departure slot.		
Immediately prior to departure slot, calls ATC for release.		
	Provides release and void time.	
Confirms ADS-B and APDLC operation.		
As departure slot becomes available, taxis on to runway and initiates the departure.		

5.11 Flying a Departure

The SATS pilot would depart the airport according to the departure procedure. Once the aircraft transitions the SCA boundary (either laterally or vertically), ATC would begin providing traditional ATC services expected for IFR aircraft. The pilot would contact ATC while climbing out on the HVO departure procedure (fig. 19). The scenario sequence for this operation is shown in table 11.
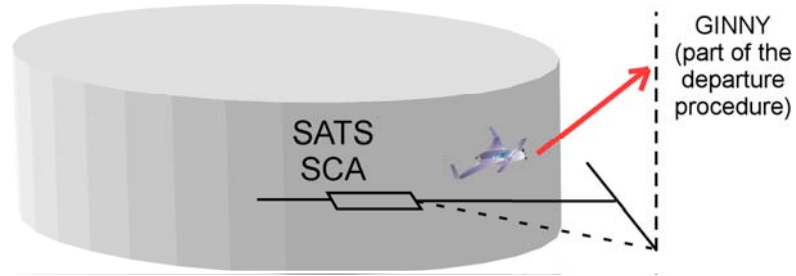
Figure 19. Departure.

Table 11. Flying a Departure.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Departs the airport on a departure procedure. Establishes contact with ATC. Transitions into traditional ATC controlled airspace.	ATC provides IFR services.	

5.12 Multiple Departures

If an aircraft immediately preceded another departure operation, the second departing aircraft would have to perform an additional procedure to assure separation safety, beyond that defined in the previous section. If the preceding aircraft was departing on another departure route (e.g., to ELLEN), then the second aircraft would wait until the first departure reached a point on the route that assured safe lateral separation (e.g., 3 nm). If the aircraft was departing on the same route, then sufficient longitudinal separation must be assured throughout the procedure, including the transition into traditional ATC controlled airspace. Techniques similar to the determination of arrival separation for departing aircraft could be used for the determination of longitudinal separation on departure. One simple example of this technique would be to require the first departure to be 10 nm along the departure procedure (fig. 20) before the second aircraft would be allowed to request an IFR release. The scenario sequence for this operation is shown in table 12.
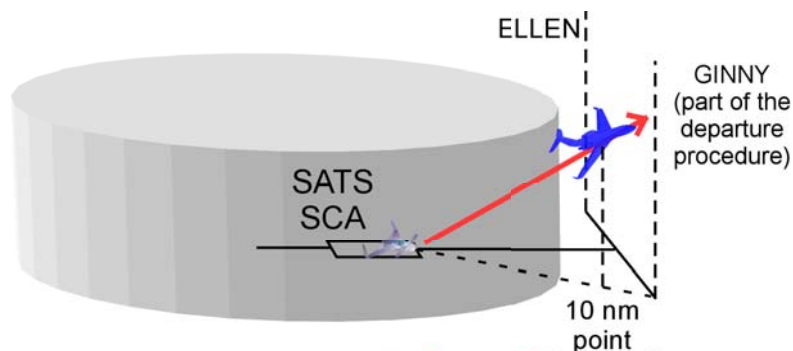
Figure 20. In-trail departure.

Table 12. Multiple Departures.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Perform procedures defined in *Initiates a Departure*, modified as noted below. Immediately prior to ETD, resolves a departure slot with arriving aircraft. Immediately prior to ETD, resolves a departure slot with departing aircraft. Prior to departure slot, calls ATC for release. As departure slot becomes available, taxi on to runway and initiates the departure.	Provides release and void time.	

5.13 Initiating a Departure from a Missed Approach

As noted in the *Initiating a Missed Approach* section, the aircraft would be automatically re-sequenced for another approach. If the SATS pilot decided that he wished to depart the SCA and transition into traditional ATC controlled airspace, he would obtain an IFR clearance from ATC. This may be done using any of today's tools including the techniques identified in the *Initiating a Departure* section. Until a clearance and a subsequent IFR release were received, the SATS pilot would hold at the MAHF at the lowest available altitude.

It should be noted that once all of the previously sequenced aircraft land, this departing aircraft would effectively block all other approach operations in the SCA since this aircraft would be the first aircraft in the approach sequence. While several techniques have been examined to mitigate this situation, they all require further study.

Once this departing aircraft received its IFR release, the SATS pilot would fly the lateral track of the approach procedure. Unless receiving alternate transition instructions from ATC, upon turning onto the final approach course, the SATS pilot would initiate a climb to transition out of the SCA (fig. 21). The scenario sequence for this operation is shown in table 13.

25
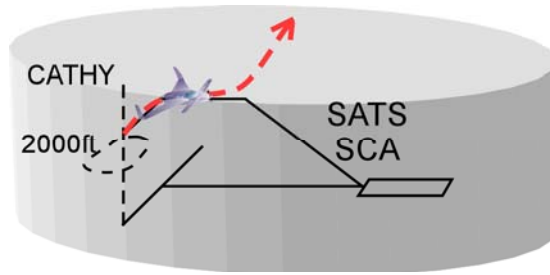
Figure 21. Departure from a missed approach.

Table 13. Departure from a Missed Approach.

Sequence of Events		
SATS Aircraft / Pilot	ATC	AMM
Holds at the MAHF. "Air files" an IFR flight plan. With normal approach sequencing and separation, initiates approach procedure (without descent). On final approach course, initiates climb to depart SCA.	Provides IFR clearance and IFR release to enter traditional ATC controlled airspace.	

5.14 Non-Equipped IFR Aircraft

An aircraft not equipped for SATS operations could use the SATS airport in a manner that would be identical to current IFR operation. As in today's systems, the non-SATS pilot would request an instrument approach or departure from ATC. ATC would then communicate with the AMM to inhibit the AMM from accepting any new SATS HVO requests (fig. 22). The AMM would also provide ATC with the number of current operations so that ATC may estimate the expected delay time until all current SATS HVO operations were completed. The AMM would then notify ATC when the SCA becomes sterile and also that the AMM was now inhibited from further SCA operations. At this time, ATC could clear the non-SATS airplane for a normal IFR operation. Once this operation was completed, ATC would communicate with the AMM to remove the "inhibit" of the AMM so that the AMM could accept new SATS HVO requests. The scenario sequence for this operation is shown in table 14.
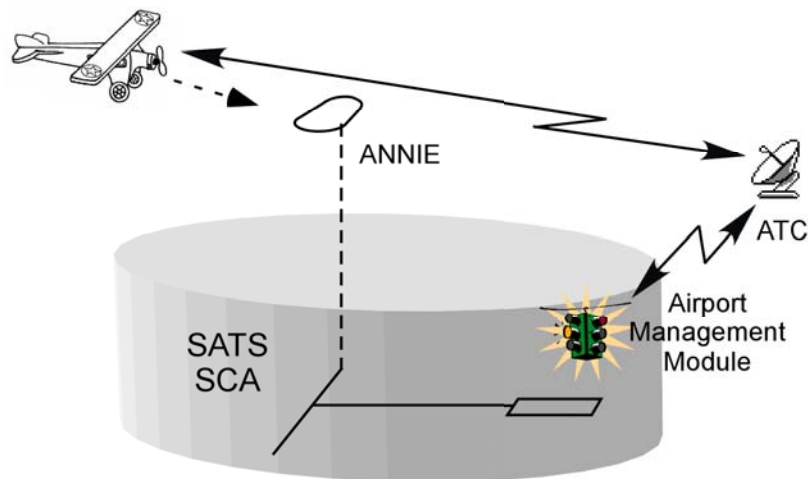
Figure 22. Non-equipped IFR aircraft.

Table 14. Non-Equipped IFR aircraft.

Sequence of Events		
Non-SATS Pilot	ATC	AMM
Requests a traditional IFR departure or approach from ATC.		
	Acknowledges the IFR request.	
	Sends an inhibit message to the AMM.	
		Inhibits all new operations. Sends a "sterile" and AMM inhibited message to ATC after all HVO operations have been completed.
	Clears pilot for IFR operation.	
Completes operation, cancels IFR.		
	Sends a message to the AMM to terminate the "inhibit."	

6.0 Off-Nominal Operations

During the development of the off-nominal operational procedures, it was recognized that procedures cannot be written for every possible scenario, and that voice communication will sometimes be essential in safely concluding an off-nominal operation. Development of these proposed off-nominal operations will still require a safety fault tree analysis and experiments to validate them. This paper offers one possible implementation, i.e., using a MFD and a PA. However, other implementation schemes are possible, and the PA functionality is not a requirement of HVO.

6.1   Off-Nominal Categories

The off-nominal conditions that were identified for inclusion into the HVO procedures were classified into four categories: routine off-nominal operations, procedural deviations, equipment malfunctions, and aircraft emergency procedures.

6.1.1 Routine Off-Nominal

The routine off-nominal operations that were identified included:

- A pilot cancellation of an approach request.

- A change of landing approach direction.

- A pilot cancellation of a departure request.

- Unique approach spacing requirements.

6.1.2 Procedural Deviations

The procedural deviations that were identified included:

- An aircraft returning to an incorrect MAHF.

- A loss of aircraft-to-aircraft spacing on approach.

- The inability to use an assigned IAF or MAHF.

6.1.3 Equipment Malfunctions

The equipment malfunctions that were identified included:

- The loss of aircraft state data output on an arriving aircraft.

- The loss of aircraft state data output on a departing aircraft.

- The loss of aircraft state data input on an arriving aircraft.

- The loss of aircraft state data input on a departing aircraft.

- The loss of the AMM.

- The loss of AMM reception by a single aircraft.

- The loss of voice radio communication capability.

6.1.4 Emergency Procedures

The emergency procedures that were identified included the following:

- A priority-landing request from an aircraft with an entry notification.

- A priority-landing request from a departing aircraft.

Examples of these two emergency conditions are shown in figures 23 and 24. Figure 23 is an example of a priority-landing request from an aircraft holding for an approach at ANNIE at 3000 ft. In this figure, the aircraft at the highest altitude has made a priority request and will ultimately be allowed to follow the aircraft on final approach, landing ahead of the aircraft holding at the lower altitudes. Figure 24 is an example of a priority-landing request from a departing aircraft. This condition would occur if an aircraft conducting an HVO departure needed an unplanned, immediate return to the airport. In this figure, the departing aircraft (the right-most aircraft) has made the landing request and will be allowed to land before the two aircraft on the farther holding patterns.

The procedures that were developed to support these identified conditions are provided in the subsequent sections.
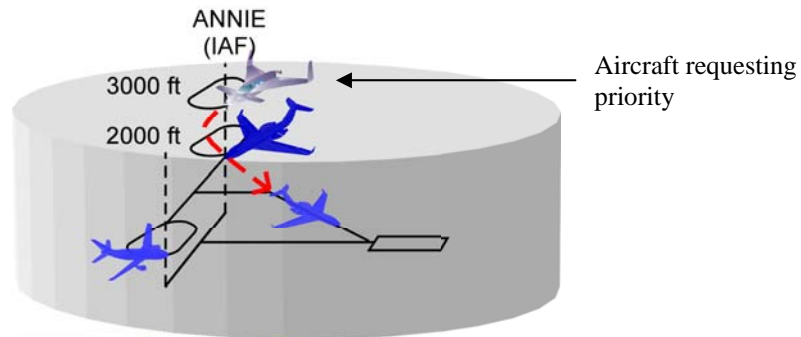
Figure 23. Example of a priority-landing request.
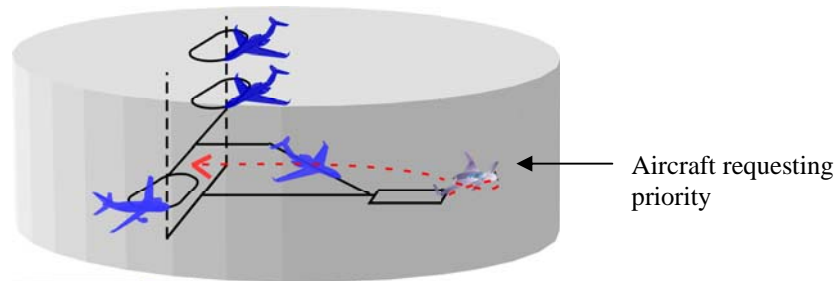
Figure 24. Example of priority landing request from a departing aircraft.

6.2   Implementation Considerations for Off-Nominal Operations

The addition of off-nominal operations in this document, and the development of their operational procedures have, not surprisingly, led to some increase in the overall complexity of the concept required to support these operations. However, as in the development of the normal operational procedures, these procedures were based, whenever possible, on similar existing procedures for VFR operations or non-radar, IFR operations. Also, with regard to VFR operations, it is important to reiterate that the normal operational procedures allow for mixed operations of both SATS and VFR aircraft, where these operations are expected to be accommodated in a manner similar to today's mix of procedural-IFR and VFR aircraft, i.e., the pilot is responsible to see and avoid other traffic (ref. 14).

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Some, off-nominal operations, especially the detection of equipment failures, will require a method for checking the operation of the different hardware and software systems. Periodic system-to-system checks and some data retention outside of the AMM can help mitigate the effects of these types of off-nominal operations. As such, the following requirements were identified to support the off-nominal procedures.

- Changes to the SCA state data information must be confirmed (performed in two phases)

  1. System-to-system (e.g., AMM to the aircraft via the APDLC) information exchange would require confirmation from the receiver back to the sender.

  2. A confirmation process within the aircraft would be required between the aircraft systems and the pilot (e.g., the pilot would be alerted to a change and would respond with the activation of a confirmation/accept button on the MFD).

- Periodic AMM status messages would be sent to all participating aircraft.

- Periodic ADS-B reception messages from the AMM would be sent to participating aircraft. After the AMM has received an ADS-B message from the aircraft, it would periodically reply with a message back to the aircraft noting that the aircraft's ADS-B message has been received. This message is necessary to alert aircraft to a loss of their ADS-B output or APDLC input capabilities.

- Prior to takeoff, departing aircraft would require the reception of both an AMM normal-operation status message and an ADS-B reception message from the AMM.

- Current SCA status information (e.g., the number of operations and aircraft identification) would be sent from the AMM to all participating aircraft.

- Each participating aircraft would retain state data from the AMM on all surrounding SCA traffic. This information would be used by the pilots in situations when a reversion to pilot-to-pilot procedural separation is required due to the loss of aircraft state data information. These situations would be analogous to ATC procedures upon the loss of ATC radar information.

- Periodic AMM normal-operation status messages would be sent to ATC (e.g., the number of operations and aircraft identification).

It is also important to note that while ADS-B would be the primary means for the dissemination of aircraft state data, the APDLC could be used to provide a secondary means for data exchange. Therefore, failures such as the loss of state data transmission are procedurally addressed only if all means of transmission have failed.

In the event of any system failure that would result in the aircraft reverting to procedural separation (noted in the subsequent sections), it is envisioned that the PA, using the retained SCA status information and the retained participating aircraft state data, would assist the pilot in performing the relevant HVO procedure.

Also note that any situation that would require closing the airport, e.g., a single-runway airport with the runway closed due to an accident, would require all approach aircraft to conduct a procedure similar to *Initiating a Departure from a Missed Approach*, described in section 5.13.

6.3 Routine Off-Nominal Procedures

6.3.1 Pilot Cancellation of an Approach Request

It is envisioned that this procedure would be used when weather conditions within the SCA would be marginal VFR and with the instrument approach operation transitioning to a visual approach. For a pilot to cancel an HVO approach, VFR conditions to the airport must exist (although the aircraft may remain on an IFR flight plan). An example of this situation is shown in figure 25.

Canceling aircraft:

1. The pilot would select the "cancel approach" feature on the MFD.

2. The MFD would send the cancellation request to the AMM.

3. The AMM would send a cancellation notice to all aircraft.

4. The MFD would notify the pilot that his cancellation request was received by the AMM.

5. The AMM would mark the aircraft as a non-participating aircraft (i.e., it is assumed that the aircraft has transitioned to VFR).

6. If the canceling aircraft has not received an entry notification (i.e., it was outside the SCA with a standby notification), the AMM would delete the aircraft from its request queue.

7. If the aircraft had received an entry notification:

   - The canceling pilot would announce the cancellation over the Common Traffic Advisory Frequency (CTAF).

   - The AMM would remove the canceling aircraft from the approach sequence.

   - The AMM would re-sequence the aircraft that followed the aircraft canceling HVO.

   - The AMM would send the new sequence information to all aircraft.
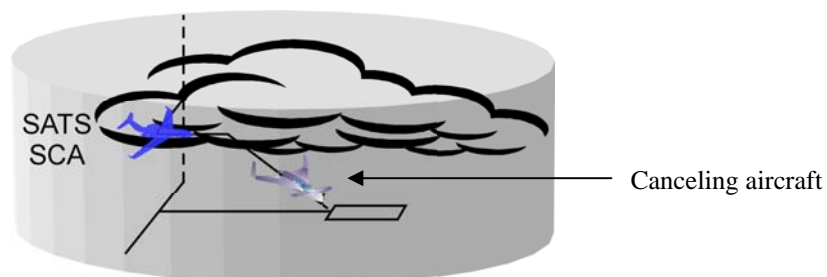
Figure 25. Example of an aircraft canceling a HVO approach.

Other aircraft:

1. The MFD would identify the canceling aircraft as a non-participating aircraft.

2. If the aircraft had an approach sequence and that sequence was changed (i.e., re-sequenced by the AMM), the MFD would notify the SATS pilot to the changes in the approach information (e.g., new leading aircraft and/or MAHF).

3. The MFD would inhibit all continuing-operations PA messages (e.g., OPEN: 3000, OPEN: APPROACH) until the pilot of the re-sequenced aircraft acknowledged the re-sequence. This acknowledgement could occur via a button-press on the MFD.

Note that for this and all other procedures that require an information exchange (e.g., cancellation request or re-sequence data) between the pilot and the onboard system, an acknowledgement by the pilot would be required. Similarly, an information exchange between the onboard system and the AMM would also require an underlying (system-to-system) data exchange confirmation (e.g., an acknowledgement). This acknowledgement could occur via a data link "handshake" between the two systems. The scenario sequence for this operation is shown in table 15.

Table 15. Pilot Cancellation of an Approach Request.

Sequence of Events		
Canceling Aircraft	Other SATS HVO Aircraft	AMM
Pilot selects "cancel approach." MFD sends cancellation request to the AMM. MFD confirms cancellation to the pilot.	 MFD identifies the canceling aircraft. If re-sequenced, MFD notifies pilot of change of approach information. If re-sequenced, continuing-operations inhibited until pilot acknowledges the re-sequence.	 Sends a cancellation notice to all aircraft. Marks the canceling aircraft as a non-participating aircraft. Re-sequences approach aircraft. Sends new sequence information.

6.3.2   Change of Approach Direction

The decision of determining the direction for the approach and the active runway should probably be made by ATC, and may require new ATC support tools for this determination. However, pilots should be allowed to provide feedback and input into the decision. Further investigation of this issue is required, to determine the best method for making this decision.

Normal changes of runway landing direction should be made prior to aircraft being provided entry notifications. That is, prior to changing landing direction ATC should inhibit new arrivals until all ongoing SCA operations have been completed, holding the new arrivals above the SCA until all current SCA operations have been completed. The SCA approach direction may not need to change if circle-to-land operations are used. Assuming that a change to the instrument approach direction must take place while aircraft are conducting SCA approach operations, the following should occur (the scenario sequence for this operation is shown in table 16):

1. The AMM should inhibit all new SCA operations.

2. The AMM should notify ATC that the SCA is in an inhibit status.

3. The AMM would confirm the planned configuration change with ATC and identify all active aircraft.

4. All landing aircraft should either land or conduct a missed approach operation.

5. Missed approach aircraft should contact ATC to obtain a clearance to the MAHF at the lowest IFR altitude above the SCA.

6. At the completion of all HVO approach operations, which would occur when all aircraft have either landed or are no longer actively conducting SATS operations, the AMM would reconfigure the SCA for the new landing direction.

7. Once all of these actions have occurred, ATC may allow the AMM to resume SCA operations.

Table 16. Change of Approach Direction.

Sequence of Events		
HVO Aircraft	ATC	AMM
Land in sequence or conduct missed approach operations. Missed approach aircraft must contact ATC for a clearance and then depart the SCA.		Inhibits all new operations. Notifies ATC of inhibit status and change of landing direction. After all HVO operations have terminated, changes the landing direction. Notifies ATC of change of landing direction.
	If desired, enables new HVO operations via AMM.	

6.3.3   *Pilot Cancellation of a Departure Request*

If a pilot cancels an SCA departure request, the following should occur:

1.   PA alerting would be inhibited for the canceling aircraft.

2.   All other aircraft would continue with their normal operations.

The scenario sequence for this operation is shown in table 17.

Table 17. Cancellation of a Departure Request.

Sequence of Events		
Canceling Aircraft	Other SATS HVO Aircraft	AMM
PA alerting is inhibited.	Continue normal operations.	

6.3.4   *Leading Aircraft Conducting a Circle-to-Land*

This situation would occur if the leading aircraft plans to conduct a circle-to-land operation. For this situation, the following procedure should be used:

1.   The pilot of the circle-to-land aircraft would select this function on the MFD.

2.   The MFD of the circle-to-land aircraft would send the circle-to-land information to include the intended landing runway to all aircraft.

3.   The following aircraft would delay initiating its approach until the circle-to-land aircraft has landed or performed a missed approach.

The scenario sequence for this operation is shown in table 18.

Table 18. Circle-To-Land.

Sequence of Events		
Circle-To-Land Aircraft	Following Aircraft	AMM
Pilot selects circle-to-land function on MFD. Aircraft sends circle-to-land notification to all aircraft.	Delays the approach until the circle-to-land aircraft completes its operation.	

6.4   Procedural Deviations

6.4.1   Aircraft Proceeding to an Incorrect Missed Approach Holding Fix

This procedure addresses the problem of an HVO pilot attempting to fly an incorrect missed approach procedure for the instrument approach. Note that for a pilot to turn toward the wrong MAHF, the pilot would have already made the following errors: performed the incorrect missed approach procedure; ignored the MAHF identified in the MFD "to waypoint" data block; ignored the missed approach procedure depicted on the moving map display of the MFD (and any associated primary flight guidance information on the Primary Flight Display - PFD); and ignored the PA alert for an incorrect missed approach procedure.

In the event that an aircraft does accidentally attempt to return to the wrong MAHF, the following procedure should be performed once the pilot recognizes the error (e.g., observes the correct MAHF name on the MFD):

1.   The pilot should make a call over CTAF announcing the problem.

2.   The pilot should contact ATC as soon as possible and announce the problem.

3.   Due to the potential loss of separation with other aircraft on the instrument approach, this aircraft must not attempt to return to the assigned MAHF. The pilot should continue climbing along the errant missed approach path to an altitude above the SCA.

4.   The pilot should immediately contact ATC and request an IFR clearance from ATC. If possible, this clearance should be obtained prior to departing the SCA.
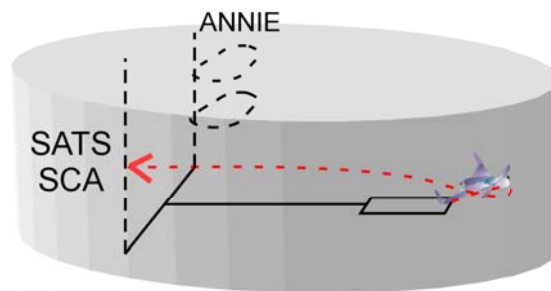
Figure 26. Example of an aircraft going to an incorrect MAHF.

An example of this scenario is shown in figure 26 and the scenario sequence for this operation is shown in table 19.

Table 19. Aircraft Going To an Incorrect MAHF.

Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
Pilot notifies other aircraft of problem via CTAF		
Pilot notifies ATC of problem.		
Pilot continues climb above SCA.		
Pilot requests ATC clearance.		

6.4.2 Loss of Aircraft-To-Aircraft Spacing on Approach

An aircraft that is predicted to lose aircraft-to-aircraft spacing while on the approach and subsequently receives a loss-of-spacing alert should do the following:

1. Begin an immediate climb to its missed approach altitude.

2. Fly the lateral path of the approach and subsequent missed approach.

3. Fly the planned approach speeds (to maintain conformance for other SCA aircraft), where these speeds are either standard speeds for the aircraft or pre-selected by the pilot.

An example of this scenario is shown in figure 27 and the scenario sequence for this operation is shown in table 20.
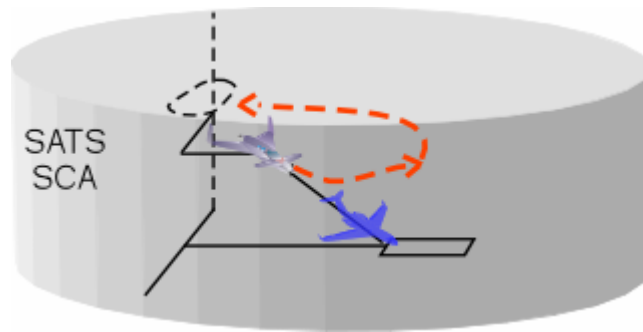
Figure 27. Example of an aircraft with a predicted loss of spacing on approach.

Table 20. Loss of Spacing on Approach.

Sequence of Events		
Following Aircraft	Other SATS HVO Aircraft	AMM
Climbs to the missed approach altitude.		
Flies the lateral path of the approach, to include the missed approach.		
Maintains the planned approach speeds until crossing the runway threshold.		

6.4.3 *Unable to Use an Assigned IAF or MAHF*

This condition may occur because of severe weather at the IAF or MAHF.

If this situation occurs while still in ATC managed airspace, the pilot should coordinate with ATC to proceed to the other IAF or divert to another airport.

If the aircraft is within the SCA when this situation occurs, the pilot should climb above the SCA in the safest possible manner, avoiding obstacles, other aircraft, and severe weather. During the climb, the pilot should notify ATC of the situation. Contacting ATC is a priority since the aircraft could be entering controlled airspace without a clearance. The scenario sequence for this operation is shown in table 21.

Table 21. Unable to Use an Assigned Fix.

Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
Contacts ATC and requests a new clearance.		
Climbs to an altitude above the SCA.		

6.5 Equipment Malfunctions

6.5.1 *Loss of ADS-B Output on an Arriving SATS Aircraft*

This situation would occur if an arriving aircraft had lost the capability to transmit its state data information via ADS-B. If this situation exists, the following should occur:

Aircraft Without an Arrival Sequence:

Part of the arrival sequencing process that the AMM performs is the confirmation of ADS-B state data output from the requesting aircraft. If the aircraft has not already been issued an arrival sequence, the AMM would attempt to confirm the aircraft's ADS-B transmit capability (and all other data output capabilities) prior to the sequence notification. If there is no ADS-B output, the aircraft would be notified of this condition, and it would be not be provided with an entry notification.

Aircraft With an Entry Notification and with APDLC Output:

If the aircraft has an entry notification and subsequently loses its ADS-B output but still has APDLC capability, the following should occur:

1. The AMM, noting the loss of the ADS-B signal from an aircraft, would inhibit all new SCA operations.

2. The AMM would notify ATC that the SCA is in an inhibit status.

3. The AMM, noting the loss of an ADS-B signal from an aircraft, would send that aircraft a "lost ADS-B output" message that could be displayed as an alert message on the MFD. The problem aircraft would then begin (or continue) transmitting its position data over the APDLC. This APDLC message would be broadcast to all aircraft in the SCA.

4. The AMM would resume normal operations after the problem aircraft has landed. The AMM would then also set the SCA status appropriately.

The scenario sequence for this operation is shown in table 22.

Table 22. Arriving Aircraft Without ADS-B Output But With APDLC Output.

Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
Transmits position data via the APDLC.		Identified loss of ADS-B output and inhibits new operations into the SCA. Notifies ATC of the inhibit status. Sends a lost-data message to the problem aircraft. Resumes normal operations after the problem aircraft lands. Notifies ATC of SCA status.

Aircraft With an Entry Notification and without APDLC Output:

If the aircraft has an entry notification and subsequently loses both its ADS-B output and its APDLC capability, the following should occur:

1. The AMM, noting the loss of an ADS-B signal from an aircraft (and all other output capability), would inhibit all new SCA operations.

2. The AMM would notify ATC that the SCA is in an inhibit status.

3. The AMM would send all aircraft a "lost signal" message via the APDLC, identifying the aircraft that had lost its transmission capability.

4. All aircraft that were conducting approach operations would revert to procedural separation using CTAF and continue the approach operations using their original sequence assignments.

5. The pilot of the problem aircraft would inform ATC when they had landed using any available means (e.g., voice radio).

6. Departure operations would be inhibited until the aircraft with the problem lands.

7. A notification to the AMM that the problem aircraft has landed or has departed the SCA would be sent from ATC.

The scenario sequence for this operation is shown in table 23.

Table 23. Arriving Aircraft Without ADS-B Output and Without APDLC Output.

Sequence of Events		
All HVO Aircraft	ATC	AMM
		Identified loss of ADS-B output and inhibits new operations into the SCA. Notifies ATC of the inhibit status. Sends a lost-data message to all aircraft identifying the problem aircraft.
Revert to procedural separation using CTAF and the original approach sequence. Problem aircraft calls ATC after landing.		
	Receives message via telephone or RCO that problem aircraft has landed. Send message to AMM.	
		Resumes normal operations.

6.5.2 Loss of ADS-B or APDLC Output on a Departing SATS Aircraft

Prior to conducting an SCA departure operation, aircraft would perform an ADS-B and APDLC check with the AMM. It is envisioned that if a successful link check could not be performed, the PA would inform the pilot that an HVO departure was not possible. In this instance, this departing aircraft would be required to revert to unequipped operations.

6.5.3 Loss of ADS-B Input on an Arriving SATS Aircraft

This situation would occur if an aircraft had lost the capability to receive ADS-B information from other SCA aircraft. If this situation takes place, the following should occur:

Aircraft Without an Entry Notification:

Part of the approach sequencing process that the AMM performs is the confirmation of ADS-B state data input to the requesting aircraft. If the aircraft has not already been issued an arrival sequence, the AMM would attempt to confirm the aircraft's ADS-B reception capability (and all other input capabilities) prior to the sequence notification. If there were no ADS-B inputs, the aircraft would be denied an entry notification.

Aircraft With an Approach Sequence and APDLC Input:

If the aircraft has an approach sequence and subsequently lost its ADS-B reception capability but still had APDLC capability, the following should occur.

1. The aircraft with the equipment problem would notify the AMM of the loss of ADS-B reception.

2. If all SCA aircraft were not already broadcasting their position data via APDLC, the AMM would request this transmission of state data via APDLC from all participating aircraft.

3. The aircraft with the equipment problem would use the APDLC-received state data as necessary.

The scenario sequence for this situation is shown in table 24.

Table 24. Aircraft With Approach Sequence, With Loss of ADS-B Input, and With APDLC Input.

Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
Notifies AMM of problem.		Requests other aircraft to broadcast state data via APDLC.
	Begin broadcasting state data via APDLC.	
Receives APDLC data and continues operation.		

Aircraft With an Approach Sequence and without APDLC Input:

If the aircraft has an approach sequence and subsequently loses its ADS-B input and its APDLC capability, the following should occur.

1. The aircraft with the equipment failure would notify the AMM of the loss of ADS-B reception capability. Lack of a periodic status message via APDLC from an aircraft could also cause the AMM to initiate this event.

2. The AMM would inhibit all new SCA operations.

3. The AMM would notify ATC that the SCA is in an inhibit status.

4. The AMM would send all aircraft an "unable to receive" message via the APDLC, identifying the aircraft that had lost its reception capability.

5. All aircraft conducting approach operations would revert to procedural separation using CTAF and continue the approach operations using their original sequencing assignments.

6. The AMM would resume normal operations after the problem aircraft has landed. The AMM would then set the SCA status appropriately.

The scenario sequence for this situation is shown in table 25.

Table 25. Aircraft With Arrival Sequence, With Loss of ADS-B Input, and Without APDLC Input.

Sequence of Events		
All HVO Aircraft	ATC	AMM
Revert to procedural separation using prior sequence and coordinating via CTAF.		Identifies loss of APDLC status message from problem aircraft. Inhibits the SCA for new operations. Notifies ATC of inhibit status. Sends "unable to receive" message to all aircraft. Resumes normal operations after problem aircraft lands. Notifies ATC and all aircraft of normal operations.

6.5.4   Loss of ADS-B or APDLC Input on a Departing SATS Aircraft

Part of the departure process that the AMM performs is the confirmation of ADS-B state data input to the requesting aircraft. The AMM would attempt to confirm the aircraft's ADS-B reception capability (and all other input capabilities). If this confirmation fails, this aircraft would be required to revert to unequipped operations.

6.5.5   Loss of AMM Output

The AMM would send a periodic operational status message to ATC and to all proximate aircraft via the APDLC. Loss of this operational status message would indicate a failure of the AMM. Upon loss of the AMM status signal, the following should occur:

1. By default, the SCA would be inhibited from accepting any new arrival or departure operations.

2. ATC would be informed of an AMM failure though the loss of the periodic status message from the AMM.

3. ATC would not allow entries to or departures from the SCA.

4. The aircraft would identify the AMM failure through the loss of the AMM status message.

5.   The MFD would provide a notification to the pilot that the AMM has failed.

6.   Pilots with an assigned arrival sequence would use CTAF to corroborate their landing sequence.

7.   Pilots would close their flight plans after landing, which is both a standard ATC normal procedure (ref. 14) and an HVO procedure. This would provide ATC a means for correlating the landing aircraft with the previously retained information that identified the current SCA traffic aircraft.

8.   At the completion of all HVO operations, the airport would revert to non-HVO operations.

The scenario sequence for this situation is shown in table 26.

Table 26. Loss of AMM Output.

Sequence of Events		
All HVO Aircraft	ATC	AMM
AMM failure identified by loss of periodic AMM status message. Perform landing using the previously assigned sequence. Close flight plan with ATC.	AMM failure identified by loss of periodic AMM status message. Restricts any new HVO operation. Revert to non-HVO procedures after last SATS aircraft closes its flight plan.	By default, no new operations would be provided.

6.5.6   *Loss of AMM Reception by a Single Aircraft*

Loss of the periodic operational status message from the AMM could indicate an APDLC receiver failure on the SATS aircraft. Upon loss of the AMM status message the following should occur:

1.   To confirm that the problem is single aircraft specific, the pilot of the aircraft without AMM reception would announce the loss of the AMM data via CTAF. If more than one aircraft has lost AMM reception, then the previous procedure (Loss of AMM Output) would be used.

2.   The pilots would use CTAF to corroborate their landing sequence.

3.   The aircraft would land in their original sequencing order.

The scenario sequence for this situation is shown in table 27.

Table 27. Loss of AMM Reception by an Aircraft.

Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
AMM or APDLC failure identified by loss of periodic AMM status message. Using CTAF, confirms loss of APDLC. Perform landing using the previously assigned sequence.	Confirms reception of AMM data.	

6.5.7 *Loss of Voice Communications*

HVO procedures were developed for the situations when aircraft have lost their voice-radio communication capability. Following normal HVO procedures assures pilots of the ability to self space within the SCA and land according to the AMM generated sequence. For aircraft in ATC airspace, standard loss-of-communication procedures (ref. 14) would be used in conjunction with the HVO arrival procedures.

Arriving Aircraft Outside of the SCA:

1. ATC would use standard lost communication procedures.

2. The lost-communications aircraft would send a "lost communications" message to the AMM via APDLC.

3. The AMM would send a "lost communications" message to ATC, confirming the loss of voice communications.

4. The lost-communications aircraft would be provided with a normal, non-priority approach sequence via APDLC, assuming that all other entry constraints were met (Sec. 5.2 and 5.3).

5. With the exception of the lost-communications aircraft, the AMM would inhibit all new operations.

6. The lost-communications aircraft should descend to the altitude immediately above the SCA at a time appropriate for traditional lost-communications procedures.

7. The lost-communications aircraft would conduct normal HVO procedures.

8. ATC would enable the AMM for new HVO operations after the lost communications aircraft has landed.

9. The AMM would then resume normal operations.

The scenario sequence for this situation is shown in table 28.

Table 28. Aircraft Loss of Voice Communications While Outside of the SCA.

Sequence of Events		
Problem Aircraft	ATC	AMM
Sends a "lost communications" message to the AMM.	Uses standard lost-communications procedures.	Sends lost communications message to ATC, identifying the problem aircraft.
		Provides a normal approach sequence to the lost communications aircraft.
		With the exception of the lost communications aircraft, inhibits the SCA for new operations.
Conduct normal HVO procedures.	Enable the AMM for HVO after the problem aircraft lands	

Arriving Aircraft Inside of the SCA:

If the aircraft had an approach sequence and subsequently lost its voice communications capability, normal operations would be continued. Voice-communication loss should not be a critical issue since the communication radio is only used as a secondary means for situation awareness and for redundancy in other off-nominal procedures. However, a loss-of-voice communication message should probably be sent to the other participating aircraft. The communication radio should be part of the minimum equipment requirement for initiating a SATS operation. A loss of voice communications does mean a loss of the CTAF environment, so transitions to VFR would have to follow existing lost-communications procedures (ref. 14).

Departing Aircraft:

Aircraft that have lost their voice communication capability and are not airborne may not conduct an HVO departure. Airborne aircraft would use traditional IFR lost-communication procedures (ref. 14).

6.6   Emergency Procedures

6.6.1   *Priority Landing Request from an Aircraft with an Approach Sequence*

This procedure would typically be used for an aircraft that is experiencing an emergency situation and must land immediately. This capability is valid only for aircraft that have an approach sequence assigned or are in a position where they would be eligible for an SCA entry notification (e.g., at the lowest available altitude over an SCA IAF). If they are not eligible for an SCA entry, they would coordinate with ATC since they are still under ATC control. Pilots within the SCA that have an emergency that precludes them from flying the complete instrument approach (engine or icing problems requiring an immediate landing) should also use these procedures. Although terrain clearance cannot be assured when

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not flying a certified approach, these procedures would ensure that all other pilots in the vicinity would have awareness of the emergency and that the emergency aircraft has landing priority.

Requesting Aircraft:

For the aircraft requesting landing priority, the following procedure should be used:

1. The pilot would announce the emergency and his intent over CTAF.

2. The pilot would select the "emergency landing" feature on the MFD.

3. The MFD would send the priority request to the AMM.

4. The AMM would inhibit all new SCA operations.

5. The AMM would notify ATC that the SCA is in an inhibit status.

6. The AMM would send the identity of the priority aircraft to all aircraft.

7. The MFD would inhibit all continuing-operations PA messages (e.g., open altitude, open approach) on the requesting aircraft.

8. As soon as possible, the priority aircraft would begin the approach, procedurally spacing with respect to prior approach aircraft. If the approach spacing interval becomes too close, the pilot of the priority aircraft has the responsibility to request the preceding aircraft to perform a missed approach. Note that the requesting aircraft will not be assigned an approach sequence. If the aircraft was initially at the higher altitude at the IAF than the approach altitude, this aircraft should only begin a normal descent (e.g., 500 foot-per-minute descent rate) after crossing the IAF inbound on the approach.

Other SCA Aircraft:

1. The aircraft symbol on the MFD for the priority aircraft would be highlighted.

2. Arriving aircraft that are already on the approach would continue with the approach procedure. If the emergency aircraft requests that the approach path needs to be immediately cleared for the emergency operation, these aircraft should execute an early missed-approach climb.

3. If the priority aircraft was already on the approach or was the first aircraft in holding at an IAF (e.g., the next aircraft to initiate the approach), the AMM would not re-sequence the other aircraft. Otherwise, the AMM would re-sequence the aircraft waiting for an approach in their original order, excluding the priority aircraft.

4. The AMM would send the new sequence information to all aircraft.

5. The MFD would notify the appropriate pilots of their re-sequence assignments.

6. The MFD would inhibit all continuing-operations PA messages (e.g., open altitude, open approach) until the pilot of the re-sequenced aircraft acknowledged the re-sequence.

7. The MFD would inhibit all approach-operations PA messages (e.g., open approach) until the priority aircraft has landed.

8. Once the priority aircraft has landed, normal operations would be resumed.

The sequence for this situation is shown in table 29 and an example of this procedure is shown in figures 23 and 28. This procedure is further examined in ref. 15.

Table 29. Priority Landing Request for An Aircraft With an Approach Sequence.

| Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
Announces problem over CTAF.		
Selects "emergency landing" on the MFD.		
MFD inhibits all continuing-operations PA messages.		Inhibits the SCA for new operations.
		Notifies ATC of inhibit status.
		Sends identification of priority aircraft to all aircraft.
	Priority aircraft highlighted on MFD.	
Conducts approach.		Re-sequences aircraft.
	If re-sequenced, all continuing-operations PA messages are inhibited until pilot acknowledges the re-sequence.	
	OPEN APPROACH messages inhibited until priority aircraft lands.	
		Resumes normal operations after problem aircraft lands.
		Notifies ATC and all aircraft of normal operations.
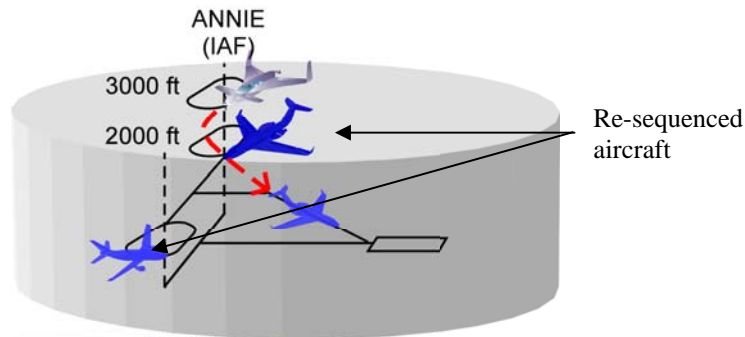
Figure 28. Example of a re-sequencing for a priority landing request.

6.6.2 *Priority Landing Request from a Departing Aircraft*

This procedure was designed to support a departing aircraft that is unable to continue the departure operation and must return for an instrument approach to the airport.

Requesting Aircraft:

Note that the first 7 steps of this procedure are the same as for Priority Landing Request from an Aircraft with an Approach Sequence.

1. The pilot would announce the emergency and his intent over CTAF.

2. The pilot would select the "emergency landing" feature on the MFD.

3. The MFD would send the priority request via APDLC to the AMM.

4. The AMM would inhibit all new SCA operations.

5. The AMM would notify ATC that the SCA is in an inhibit status and identify the priority aircraft.

6. The AMM would send the identity of the priority aircraft to all aircraft.

7. The MFD would inhibit all continuing-operations PA messages (e.g., open altitude, open approach).

8. As soon as possible, the priority aircraft would proceed to either IAF, at the lowest altitude, and begin the approach, procedurally spacing with respect to prior approach aircraft (if any). Note that this aircraft would not be assigned an approach sequence. If the approach spacing interval becomes too close, the pilot of the priority aircraft has the responsibility to request the preceding aircraft to perform a missed approach.

Other SCA Aircraft:

1. The aircraft symbol on the MFD for the priority aircraft would be highlighted.

2. Arriving aircraft that are already on the approach would continue with the approach procedure. If the emergency aircraft needs the approach path immediately cleared, the pilot of the emergency aircraft would request that the preceding aircraft execute an early missed-approach.

3. Arrival aircraft that are holding at the IAF (i.e., not already on the approach) and are at the lowest altitude would be re-sequenced, if necessary, such that they would leave the IAF for the approach as soon as possible (i.e., the intent is to make a clear approach path for the emergency aircraft). These aircraft should make every attempt to expedite their approach operations.

4. For arrival aircraft that are holding at the IAF (i.e., not already on the approach) and are not at the lowest altitude, the following should occur:

   - These aircraft would be re-sequenced, as required, for the approach.

   - If the aircraft had an approach sequence that was changed (i.e., re-sequenced), the MFD would notify the SATS pilot to the changes in the approach information (e.g., new leading aircraft or MAHF).

   - These aircraft would be given a STANDBY notification by the AMM.

   - The MFD would notify the appropriate pilots of their standby assignment.

   - The MFD would inhibit all continuing-operations PA messages (e.g., open altitude, open approach) until the pilot of the re-sequenced aircraft acknowledges the re-sequence.

   - The MFD would inhibit all continuing-operations PA messages (e.g., open altitude, open approach) until the emergency aircraft lands.

5. Normal operations would be resumed once the priority aircraft has landed.

The sequence for this situation is shown in table 30. This procedure is further examined in ref. 15.

Table 30. Priority Landing Request for a Departing Aircraft.

Sequence of Events		
Problem Aircraft	Other SATS HVO Aircraft	AMM
Announces problem over CTAF.		
Selects "emergency landing" on MFD.		
MFD inhibits all continuing-operations PA messages.		Inhibits the SCA for new operations.
		Notifies ATC of inhibit status.
		Sends identification of priority aircraft to all aircraft.
	Priority aircraft highlighted on MFD.	
Proceed to the IAF at the lowest available altitude and conduct the approach.		Re-sequences holding aircraft to provide a path for the priority aircraft.
	If re-sequenced, all continuing-operations PA messages are inhibited until pilot acknowledges the re-sequence.	
	If the aircraft is to clear the path for the priority aircraft, expedite the approach in the sequence order. Otherwise, OPEN APPROACH messages are inhibited until the priority aircraft lands.	
		Resumes normal operations after problem aircraft lands.
		Notifies ATC and all aircraft of normal operations.

An example of this procedure is shown in figures 29-32, with the chosen example portraying the worst approach sequencing situation prior to the start of this procedure. Figure 29 shows the start of this procedure, with an aircraft on the approach and three other aircraft waiting to begin the approach. The approach sequence numbers are shown in this figure for these aircraft.
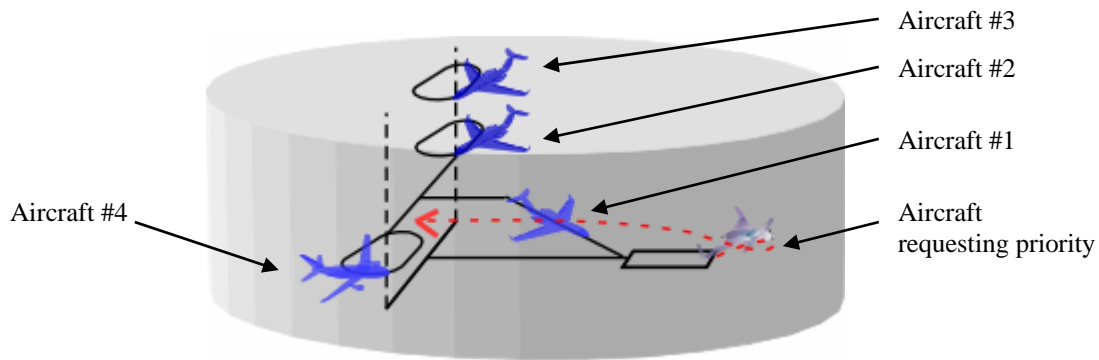
Figure 29. Example of a priority landing request from a departing aircraft: initial situation.

Figure 30 portrays the situation immediately after the departing aircraft makes the priority request. At this point, the AMM would have re-sequenced the aircraft, issued the new sequence numbers and, where appropriate, STANDBY notifications. Note that the action by the AMM has affected all of the holding aircraft.

Figure 31 shows the situation as the second aircraft begins its approach. Note that the standard HVO airborne tools, using the AMM sequencing information, have provided the information to the second aircraft that it is safe to initiate its approach. Also note that the first aircraft has landed.

Figure 32 shows the situation after the third aircraft begins its approach, again using its onboard tools to determine when to begin the approach. Figure 33 is a plan-view graphic of the situation shown in figure 32.
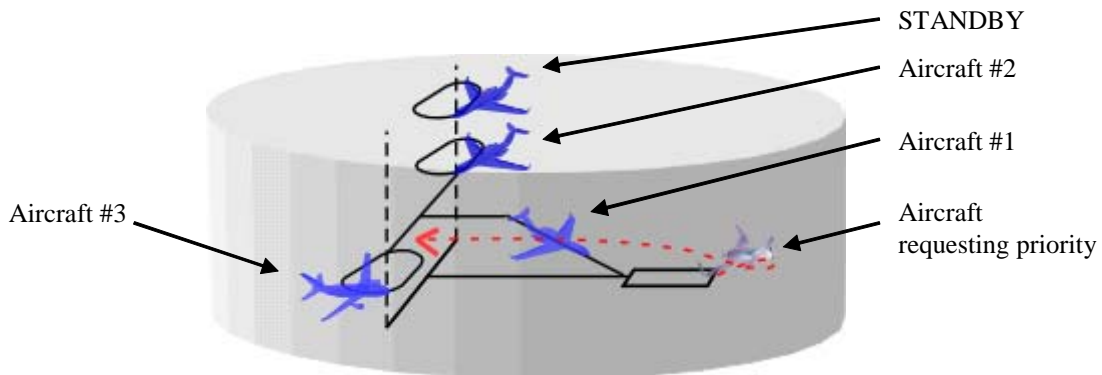
Figure 30. Example of a priority landing request from a departing aircraft: after re-sequence.
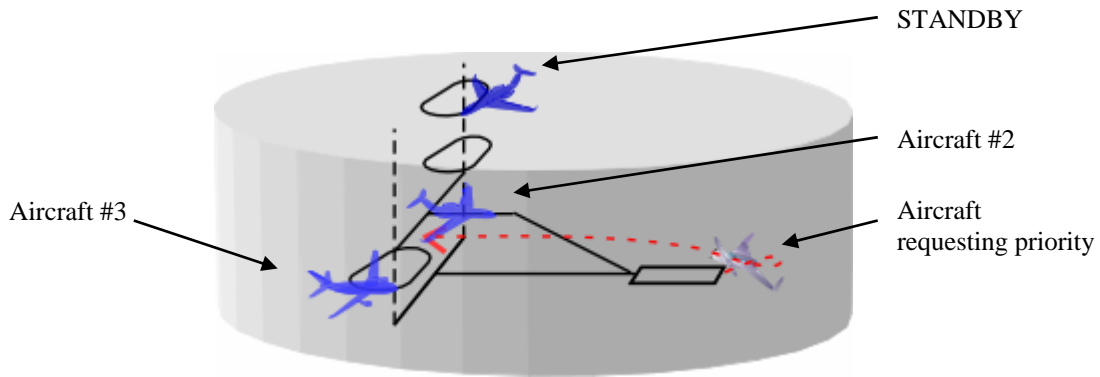
Figure 31. Example of a priority landing request from a departing aircraft: aircraft #2 begins approach.
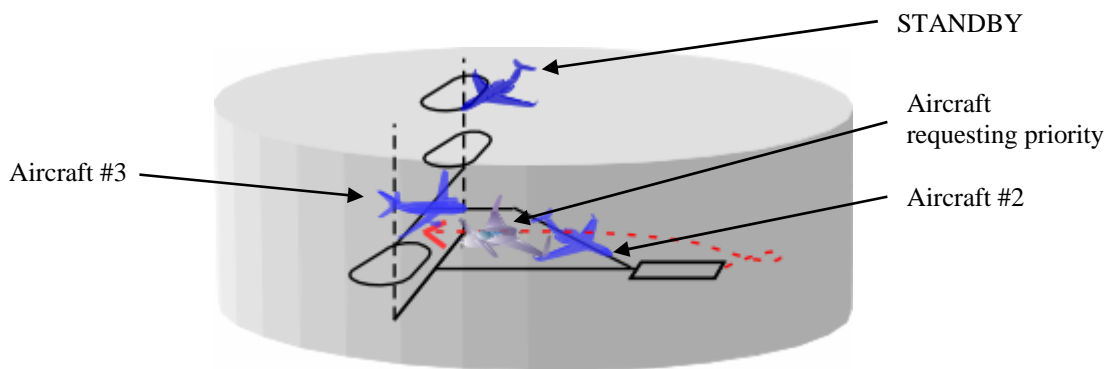
Figure 32. Example of a priority landing request from a departing aircraft: aircraft #3 begins approach.
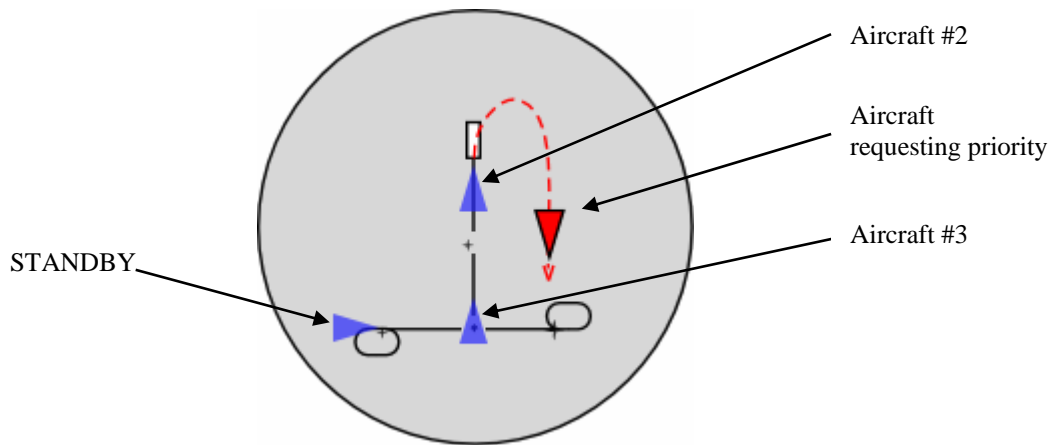
Figure 33. Plan-view of the situation of figure 32.

Figure 34 shows the situation as the priority aircraft begins its approach. Note that while the standard HVO airborne tools have provided the information to the third aircraft to initiate its approach, the pilot of the priority aircraft, because of the emergency situation, will initiate the approach as soon as possible. Also note that if the approach spacing interval becomes too close, the pilot of the priority aircraft has the responsibility to request the preceding aircraft to perform a missed approach.

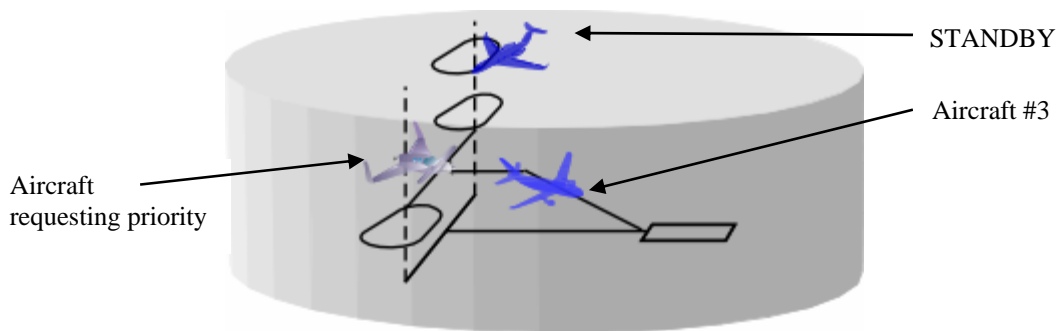Figure 34. Example of a priority landing request from a departing aircraft: priority: aircraft begins approach.

Once the priority aircraft has landed, the STANDBY aircraft will be allowed to resume approach operations. Also note that all normal operations would be resumed once the priority aircraft has landed.

7.0 Summary

This paper outlines the SATS HVO concept, which allows the operation of multiple small aircraft during periods of poor weather at virtually any small airport. This operational concept offers a unique opportunity for revolutionary transportation growth and passenger convenience. The SATS HVO concept would allow simultaneous operations by multiple aircraft to take place in the non-radar airspace around airports with no tower and limited or no radar services. Aircraft operating in this airspace would need special avionics to participate, most likely including near-term technologies, such as ADS-B and a communications data link, and appropriate self-separation tools. This concept would also require a new, relatively simple ground-based automation system that would provide appropriate sequencing information to the arriving aircraft. Although pilot and controller workload issues were not investigated experimentally for this concept definition, they were considered in the development of these new procedures, with the aim of minimizing the potential for additional workload requirements.

This paper also included descriptions of off-nominal situations that could be expected to occur in a future SATS environment. The situations that were examined were segregated into four categories: routine, such as a change of landing approach direction; procedural deviations, such as flying to the wrong MAHF; equipment malfunctions, such as a loss of an aircraft's communication system; and emergency situations, such as a priority request for an emergency landing. SATS operational procedures were developed to accommodate these off-nominal situations and were described in this paper. Additionally, since both equipment requirements and equipment malfunctions are closely interrelated in off-nominal situations, a candidate implementation scheme (i.e., display format and data links) was also presented.

This proposed operational concept emphasizes integration with the current and planned near-term NAS (ref. 16). The focus of the underlying design approach was on simplicity from both a procedural and a systems requirements standpoint. This is in keeping with the SATS goal of achieving a realistic, operationally deployable system for the 2010 timeframe. The development focus was on providing an operational concept that was safe, would enable more than one operation at a time, and would not require significant ground infrastructure costs or improvements. A significant design effort was also expended towards minimizing equipment requirements and changes to today's operating rules. The concept is based on a distributed decision-making environment that would provide pilots the necessary procedures,

tools, and information to enable safe operations within the SCA, noting that while this is a distributed decision-making environment, the majority of the decision-making responsibility would remain with the pilot.

The operational concepts and procedures described in this paper were intended to provide a foundation for additional designs and analyses. Operational concepts such as the one proposed in the fundamental SATS HVO concept documents and expanded here could enhance the opportunity for point-to-point air taxi or charter operations into smaller airports, providing greater convenience to the traveling public.

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Appendix A

SCA Procedures for Alternative Instrument Approach Designs

General

The general approach procedures for SCA operations can potentially be adapted for situations when the instrument approach procedure differs from the basic GPS T approach previously described. In considering alternative instrument approach designs in the SCA procedures, the following guidelines were used:

- The missed approach segment of the instrument approach procedure may not place the aircraft on a reciprocal path to the final approach course unless vertical separation can be assured.

- No more than two IAFs may be used for the instrument approach procedure. This restriction is based on the ability to efficiently and safely land the arriving aircraft, limiting the arrival operations to four aircraft. This four aircraft maximum is achieved with two aircraft at each IAF.

- The IAFs must have sufficient horizontal separation such that the protected areas for each of the respective holding patterns do not overlap.

- IAFs may not lie along a common path. That is, one IAF may not be on the approach path of the other IAF.

If the previous conditions can be met for an approach procedure with two IAFs, then the general SATS HVO procedures may be used.

Single IAF

For instrument approach procedures where only one IAF is possible, the SCA operating rules are modified as follows:

- No more than two concurrent arrival operations are allowed in the SCA.

- Since alternating MAHFs cannot be given to sequential aircraft, an additional separation buffer (e.g., adding an additional time to the following aircraft's spacing interval assuming similar aircraft speeds) should be given each following aircraft to provide a safety margin in the case that two sequential aircraft perform missed approach operations.

- All other SCA operating rules remain the same.

If these conditions can be met for an approach procedure with one IAF, then the remaining general SATS HVO procedures may be used. Example approach charts with one IAF are provided in figures A1 and A2. Also note that the lateral entry area would be modified with a single entry area (figure A3).

MELFA, VIRGINIA

APP CRS	Rwy ldg 4999
034 ⁰	TDZE 47
	Apt Elev 47

SATS RNAV (GPS) RWY
MELFA/ACCOMACK COUNTY (MFV)

SATS Equipped Only
GPS or RNP-0.3 required
DME/DME RNP .3 NA

Missed Approach: Climb to 2000' then climbing right turn to 3000' via LNAV path to UCGEL and hold.

| AWOS-3 118.175 | NORFOLK APP CON 126.05 | UNICOM 122.8 (CTAF) |

SATS Self Controlled Area

331 ± ∧

∧ 515

∧ 264

JAGNO (MAF and Threshold)

∧ 349

MELFA (FAF)
374 ∧

1500
034
(5)

(IAF) UCGEL

034⁰

214⁰

ELEV 47

127 ± ∧

5004 X 100

∧ 143

TDZE 47

2000

3000

UCGEL

3000 — UCGEL

2000 — 034⁰ MELFA

1500 3.00⁰
TCH 40

JAGNO

← 5 NM → ← 4.5 NM →

034⁰ TO RWY 3

∧ 136 ±

REIL Rwys 3 and 21
MIRL Rwy 3-21

CATEGORY	A	B	C	D
LNAV MDA	440-1 393 (400-1)			440-1 1/4 393 (400-1 1/4)
CIRCLING	NA			

MELFA, VIRGINIA

SATS RNAV (GPS) RWY
MELFA/ACCOMACK COUNTY (MFV)

Figure A1. Example approach chart with single IAF.

Research Only – Not for Navigation

SATS RNAV (GPS) RWY 3 AZBEJ
MELFA/ACCOMACK COUNTY (MFV)

APP CRS 034 ⁰	Rwy ldg 4999 TDZE 47 Apt Elev 47	

SATS Equipped Only GPS or RNP-0.3 required DME/DME RNP .3 NA	Missed Approach: Climbing right turn to lowest available (2000 or 3000) via LNAV path to AZBEJ and hold.

AWOS-3 118.175	NORFOLK APP CON 126.05	UNICOM 122.8 (CTAF)

CATEGORY	A	B	C	D
LNAV MDA		440-1 393 (400-1)		440-1 1/4 393 (400-1 1/4)
CIRCLING		NA		

SATS RNAV (GPS) RWY 3 AZBEJ
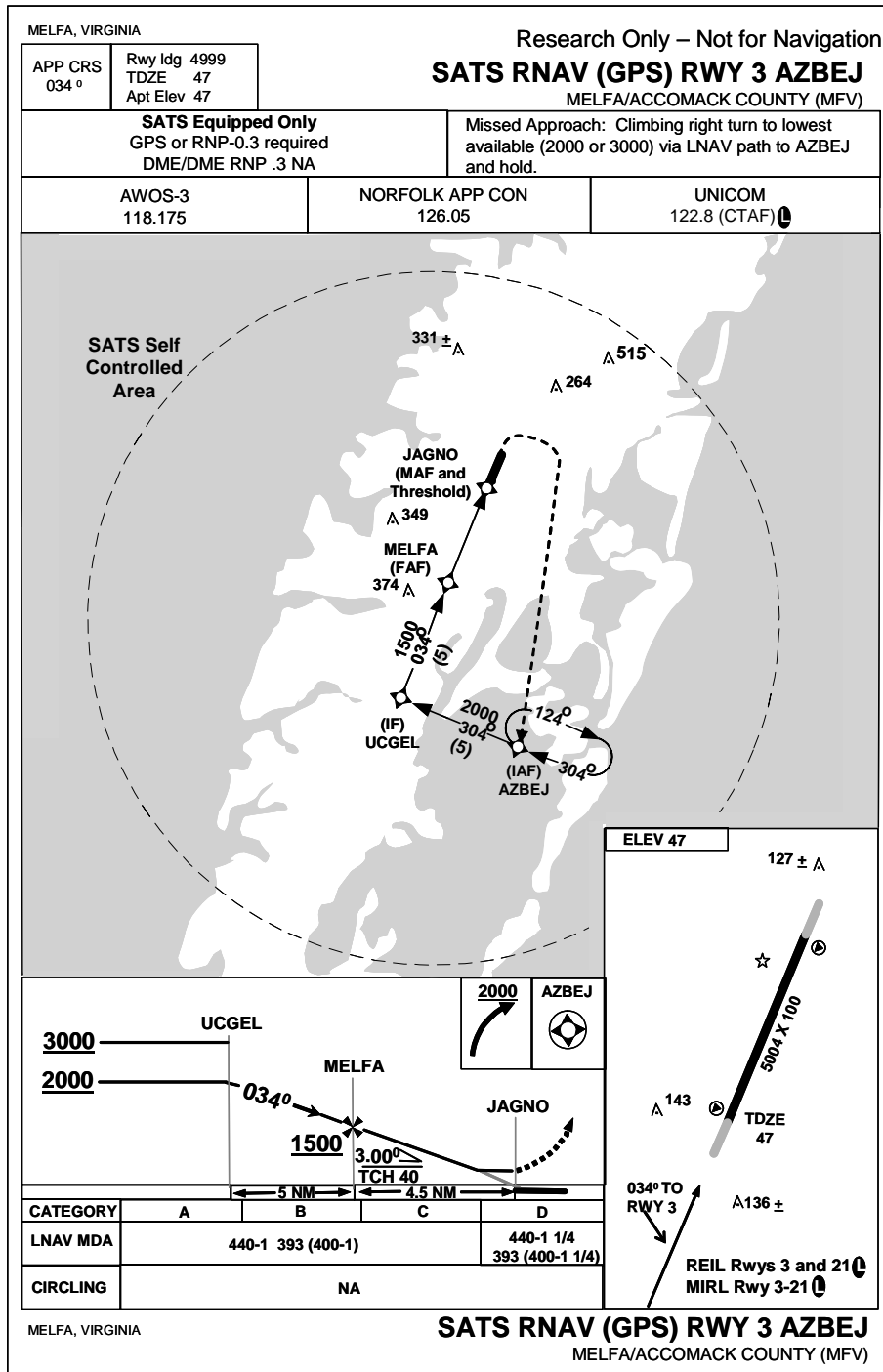MELFA/ACCOMACK COUNTY (MFV)

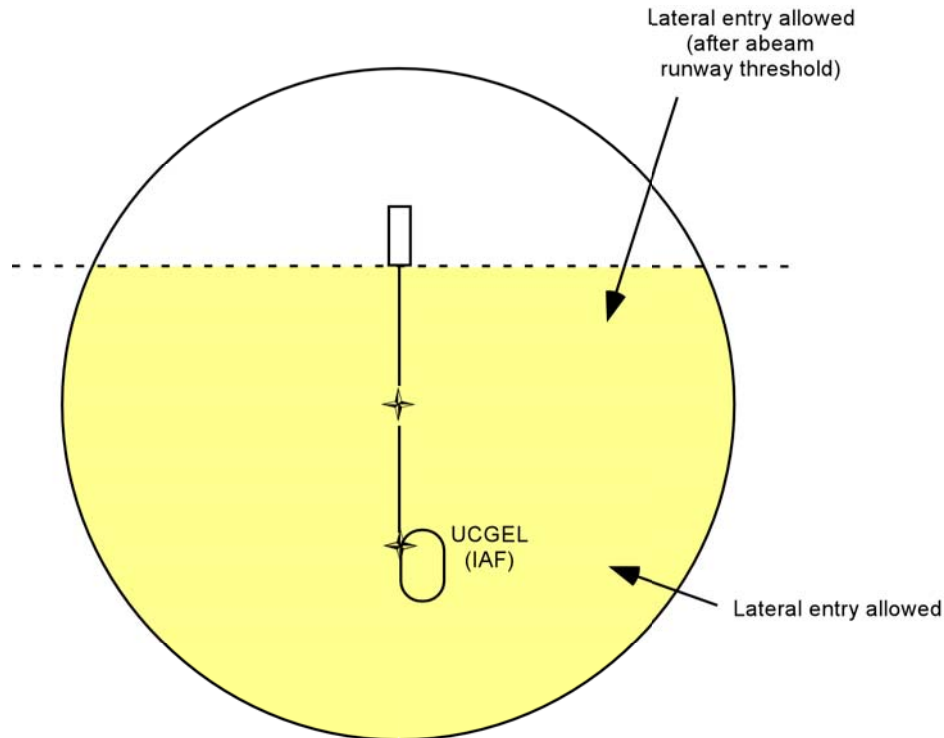Figure A2. Example approach chart with single, off-final IAF.

Figure A3. Lateral entry area for the single IAF approach shown in figure A1. Note that the yellow area extends outside of the circle.

MAHF not Co-Located with the IAF

For instrument approach procedures where, for operational reasons, the MAHF cannot be co-located with the IAF, an alternative SCA design with a complementary approach procedure may be possible. Figure A4 shows one example for this alternative design where the IAF, AZBEJ, cannot be used for the MAHF due to a 914ft obstacle between the missed approach point and AZBEJ. To employ this alternative design, the following constraints would apply:

- The MAHF and its protected area must be within the SCA.

- The missed approach segment of the instrument approach procedure may not place the aircraft on conflicting course for the instrument approach procedure unless vertical separation can be assured.

- The MAHF and the IAFs must have sufficient horizontal separation such that the protected areas for each of the respective holding patterns do not overlap.

  The procedures for SCA entry would be changed such that:

- Entries are not allowed at an IAF if any aircraft is on the approach and the MAHF for that approach is assigned as their MAHF. The AMM would count the aircraft assigned to the MAHF as also assigned to the appropriate IAF.

- Entries may not result in the assignment of more than two aircraft to a specific fix, with the assignment as either an IAF or as the IAF following the MAHF.

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Pilots assigned this MAHF and conducting a missed approach would be expected to fly to the MAHF, climb in the holding pattern until reaching the minimum altitude for the holding pattern, and then proceed to the IAF. Once the aircraft initiated the missed approach, the AMM would assign a new approach sequence using the standard HVO procedures.
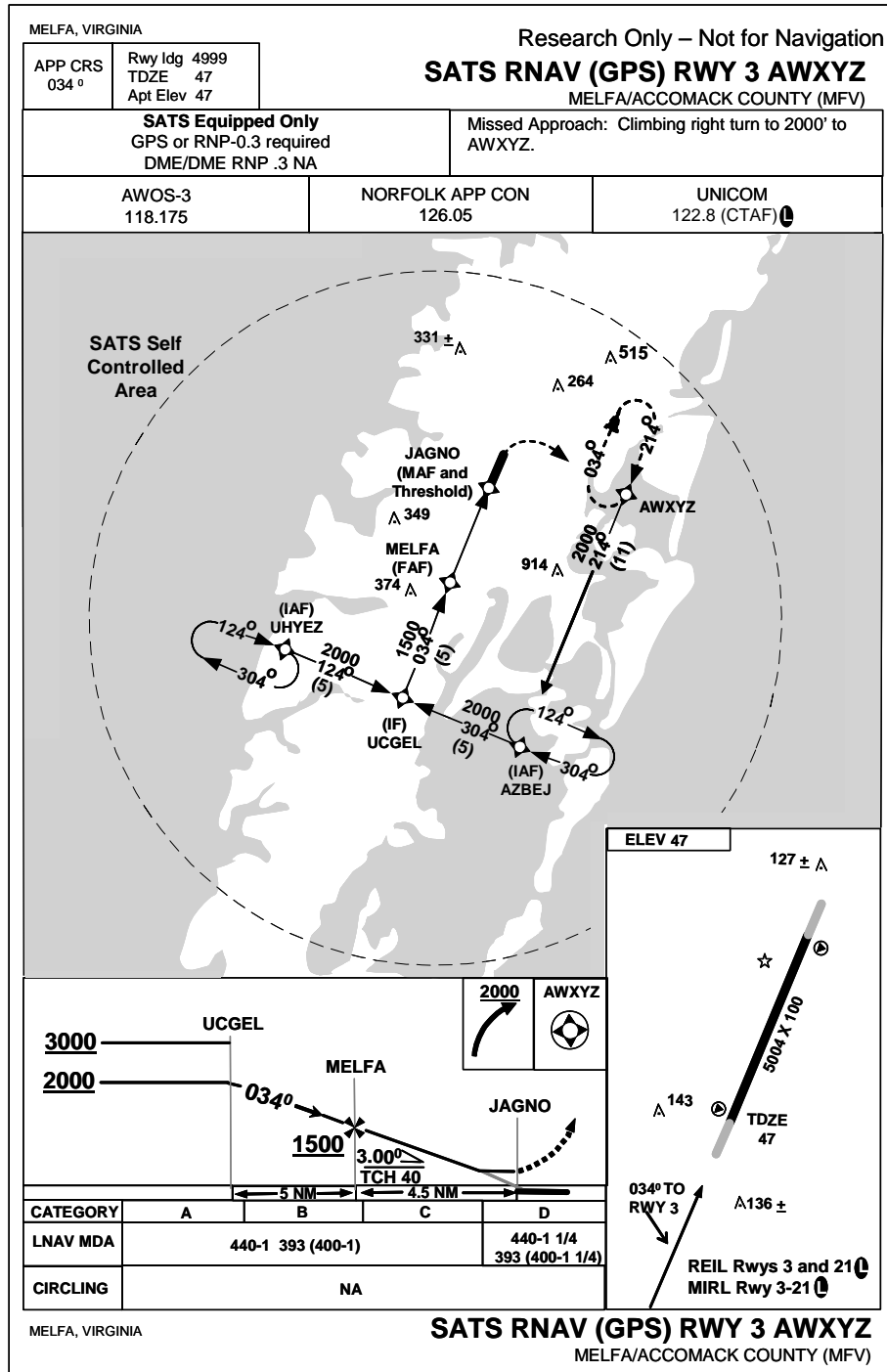

Figure A4. Example approach chart with MAHF separate from the IAF.

Appendix B

Conflict Detection and Alerting

A multilayer approach to the prevention of conflicts due to the loss of aircraft-to-aircraft separation is an explicit part of the SATS HVO design with these operations relying on both procedures and onboard automation. This multilayer approach gives pilots support and guidance during the execution of normal operations and advance warning in case of procedure deviations or off-nominal operations. These pilot procedures were designed to be both simple and robust. They have been formally proven to provide safe separation to approaching and departing aircraft in the SCA (ref. 17). Adherence to these procedures represents the first layer of this multilayer method. A second layer is provided by the procedure support automation that includes onboard conformance monitoring, approach spacing, and altitude determination tools. The conformance monitoring tool advises pilots of altitude, speed, and path deviations during all approach segments and holding patterns. The spacing tool provides in-trail approach initiation time and spacing advisories. The altitude determination tool identifies open holding altitudes within the SCA. The third layer in this conflict prevention strategy is provided by the aircraft-based Conflict Detection and Alerting (CD&A) logic which is also part of the onboard automation. To address cases of procedure deviations or off-nominal conditions, a CD&A method was developed that uses a combination of state vector and procedure-based intent for conflict detection and a multistage, asymmetrical alerting system. A schematic view of the SATS HVO multilayer conflict prevention approach is depicted in figure B1. The different layers are logically independent.
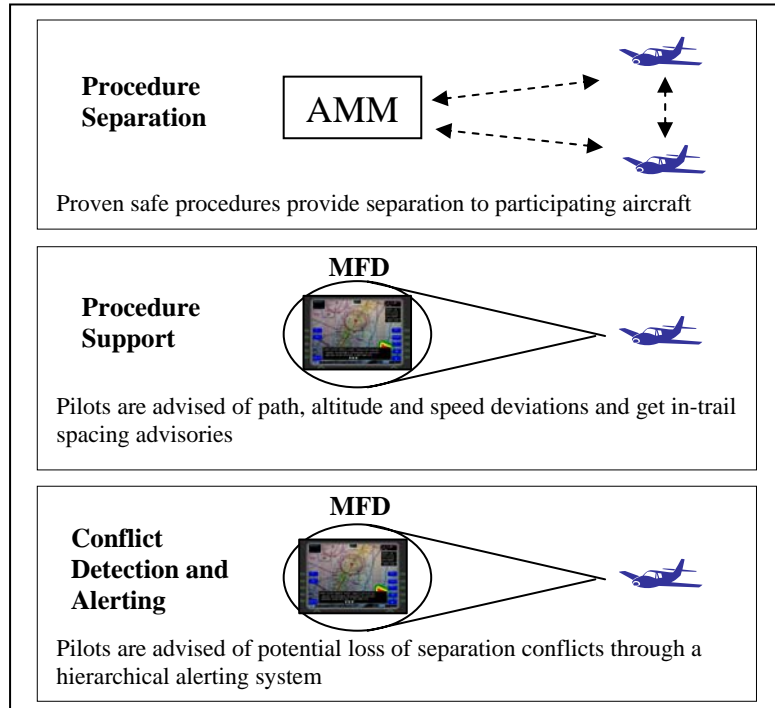

Figure B1. Schematic view of the SATS conflict prevention process.

The CD&A logic was designed to provide conflict awareness to aircraft within the SCA during off-nominal conditions such as procedure deviations and emergency operations. The CD&A logic is based on a hybrid method that uses a combination of both ADS-B state vector and intent information to predict any loss of separation while minimizing false alarms. The method uses the concept of Nominal Approach Path (NAP) conformance as part of the prediction logic. The NAP represents the implicit intent. An aircraft is in conformance to the NAP if the following conditions are satisfied:

- Aircraft enters the SCA according to the information received from the AMM, performing either a lateral or vertical entry.

- Aircraft remains within the lateral and vertical boundaries of the approach containment volume (a configurable lateral distance and altitude error that limits the accepted deviation of an aircraft from its nominal trajectory) for all segments of the approach, missed approach and holding patterns.

- Aircraft remains within its intended speed profile during all the approach segments.

- Aircraft performs a missed approach according to the assigned MAHF.
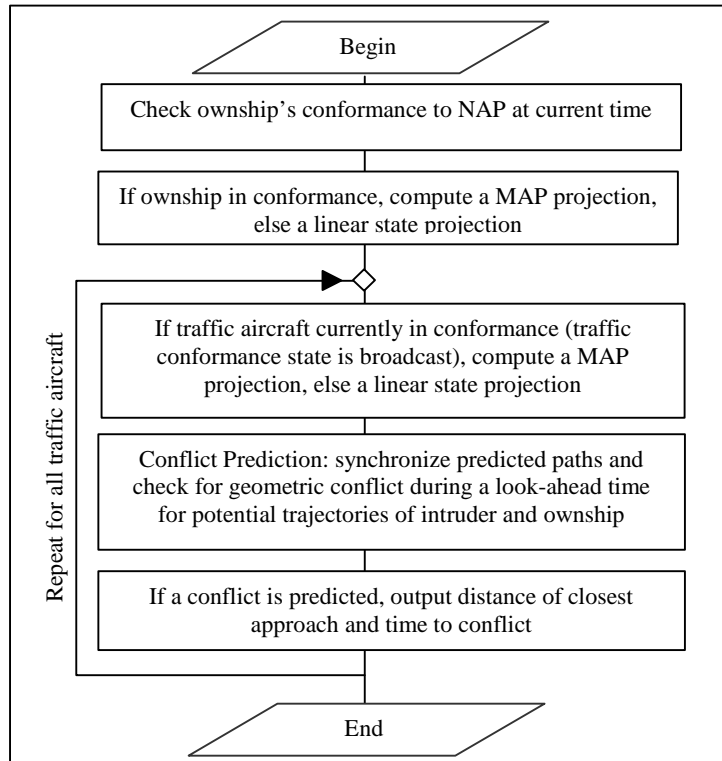
A pair-wise conflict detection logic selects state-based or NAP-based trajectory projections for the ownship (from a pilot's perspective, the aircraft that they are flying) and traffic aircraft depending on their conformance status. A NAP-based projection is used for conforming aircraft whereas a state-based projection is used for non-conforming aircraft. The rational for this hybrid trajectory prediction technique is that an aircraft in path conformance is more likely to follow the intended path. No assumptions should be made for non-conforming aircraft. For conforming aircraft, the hybrid conflict detection logic behaves as a purely intent based logic. This is a key feature to reduce false alarms that otherwise could frequently occur in terminal areas. False alarms can have an adverse effect on pilots in that they may ultimately ignore real conflicts. Preliminary simulation studies have shown that this hybrid approach outperforms state based only methods with regards to false and missed alerts. In addition, the technique has been successfully implemented and used in simulations and flight tests with very low incidence of false alerts during these tests.

The pair-wise conflict detection logic selects either a state or NAP based path propagation technique for each aircraft according to its conformance status. For an aircraft in conformance, the path propagation is based on its implicit intent along the approach, departure, or missed approach path. For an aircraft out of conformance, the path propagation is based on its state vector since no assumption should be made for an aircraft that deviates from procedure. The conflict detection logic may select different propagation techniques for ownship and the other aircraft. Once the selection is done, potential trajectories are generated and geometric conflicts are evaluated. Figure B2 shows a functional description of the algorithm.

The conflict alerting algorithm developed for SATS HVO employs a multi-stage, asymmetrical alerting scheme. Multilevel refers to the use of three levels of alerts: advisories, cautions and warnings; which are based upon the time to conflict. Asymmetrical alerting involves selecting the order and time in which pilots are notified of an impeding conflict based on a pair-wise inherently simultaneous conflict detection. While two aircraft running the conflict detection algorithm can detect a conflict simultaneously, the time at which pilots are alerted can be delayed depending on certain conditions. In particular this alerting method permits a conflicting aircraft that is out of conformance to be notified first so it can make trajectory and speed adjustments to correct its course before the conforming aircraft is notified. The same logic can be applied to trailing aircraft on approach, that if notified first can make speed adjustments to

avert potential conflicts. Resolution advisories to potential loss of separation conflicts are not automated in the current system and are part of on going research.

Figure B2. Conflict detection logic.

Begin

Check ownship's conformance to NAP at current time

If ownship in conformance, compute a MAP projection, else a linear state projection

If traffic aircraft currently in conformance (traffic conformance state is broadcast), compute a MAP projection, else a linear state projection

Conflict Prediction: synchronize predicted paths and check for geometric conflict during a look-ahead time for potential trajectories of intruder and ownship

If a conflict is predicted, output distance of closest approach and time to conflict

Repeat for all traffic aircraft

End

Appendix C

Simplified Flow Charts of Normal Arrival and Departure Procedures

A simplified flow chart of the normal arrival procedure is provided in figure C1. The departure procedure is provided in figure C2.
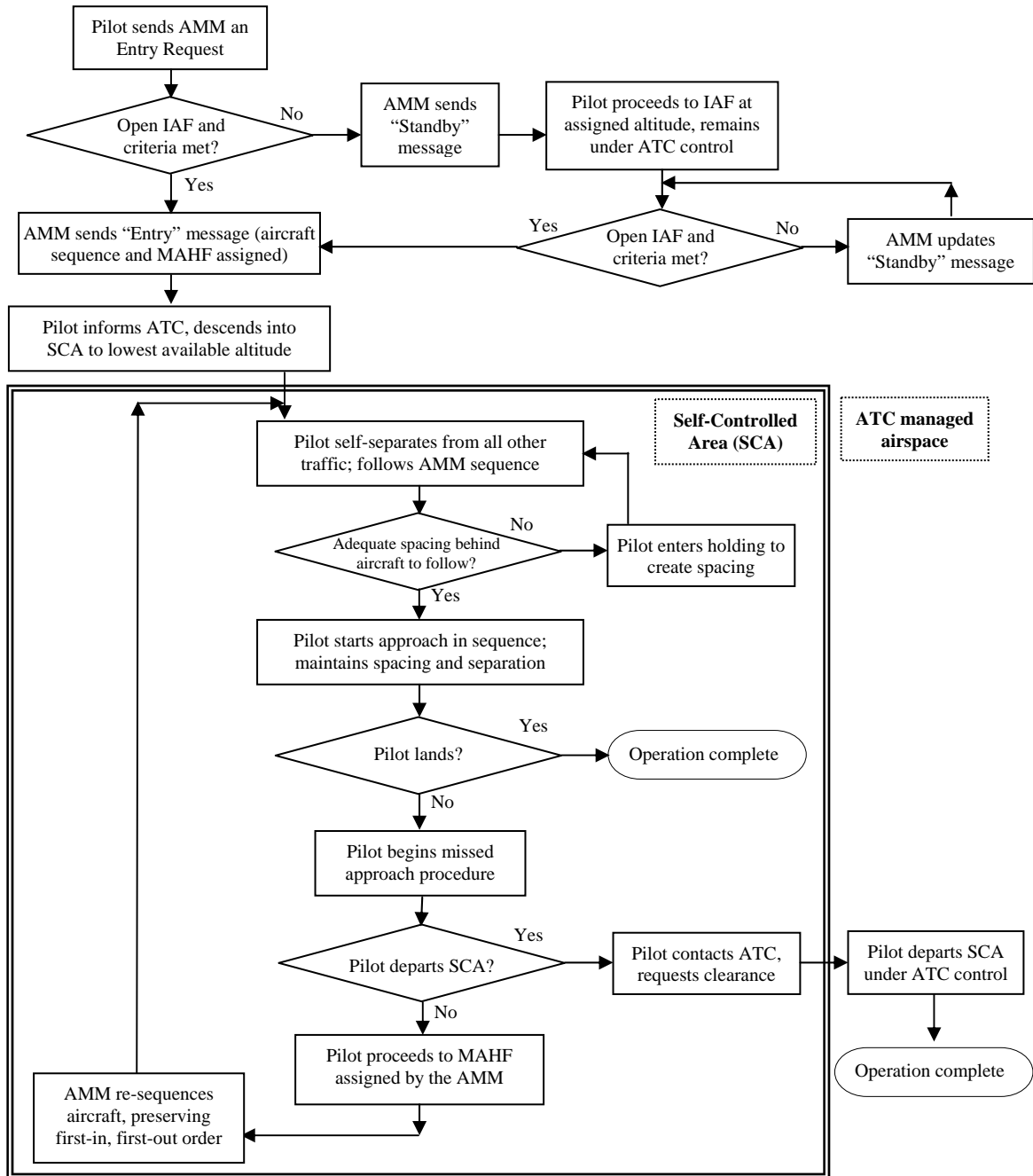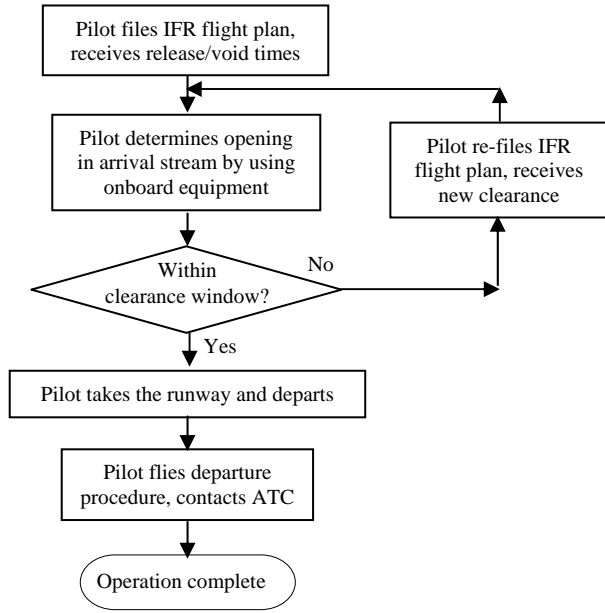
Pilot sends AMM an Entry Request

Open IAF and criteria met? — No → AMM sends "Standby" message → Pilot proceeds to IAF at assigned altitude, remains under ATC control

Yes → AMM sends "Entry" message (aircraft sequence and MAHF assigned)

Open IAF and criteria met? — Yes → (to AMM sends "Entry" message); No → AMM updates "Standby" message

Pilot informs ATC, descends into SCA to lowest available altitude

Self-Controlled Area (SCA) **ATC managed airspace**

Pilot self-separates from all other traffic; follows AMM sequence

Adequate spacing behind aircraft to follow? — No → Pilot enters holding to create spacing

Yes → Pilot starts approach in sequence; maintains spacing and separation

Pilot lands? — Yes → Operation complete

No → Pilot begins missed approach procedure

Pilot departs SCA? — Yes → Pilot contacts ATC, requests clearance → Pilot departs SCA under ATC control → Operation complete

No → Pilot proceeds to MAHF assigned by the AMM

AMM re-sequences aircraft, preserving first-in, first-out order

Figure C1. Arrival procedure.

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Pilot files IFR flight plan, receives release/void times

Pilot determines opening in arrival stream by using onboard equipment

Pilot re-files IFR flight plan, receives new clearance

Within clearance window?

No

Yes

Pilot takes the runway and departs

Pilot flies departure procedure, contacts ATC

Operation complete

Figure C2. Departure procedure.

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14. ABSTRACT

This document defines the Small Aircraft Transportation System (SATS) Higher Volume Operations concept. The general philosophy underlying this concept is the establishment of a newly defined area of flight operations called a Self-Controlled Area (SCA). Within the SCA, pilots would take responsibility for separation assurance between their aircraft and other similarly equipped aircraft. This document also provides details for a number of off-nominal and emergency procedures which address situations that could be expected to occur in a future SCA. The details for this operational concept along with a description of candidate aircraft systems to support this concept are provided.

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