THE SMALL AIRCRAFT TRANSPORTATION SYSTEM (SATS), HIGHER VOLUME OPERATIONS (HVO) OFF-NOMINAL OPERATIONS

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Abstract

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 charter operations at small airports. The Small Aircraft Transportation System, (SATS) Higher Volume Operations (HVO) concept is designed to increase traffic flow at any of the 3400 non-radar, non-towered airports in the United States where operations are currently restricted to "one-in/one-out" procedural separation during Instrument Meteorological Conditions (IMC). The concept's key feature is pilots maintain their own separation from other aircraft using procedures, aircraft flight data sent via air-to-air datalink, cockpit displays, and on-board software. This is done within the Self-Controlled Area (SCA), an area of flight operations established during poor visibility or low ceilings around an airport without Air Traffic Control (ATC) services.

The research described in this paper expands the HVO concept to include most off-nominal situations that could be expected to occur in a future SATS environment. The situations were categorized into routine off-nominal operations, procedural deviations, equipment malfunctions, and aircraft emergencies. The combination of normal and off-nominal HVO procedures provides evidence for an operational concept that is safe, requires little ground infrastructure, and enables concurrent flight operations in poor weather.

HVO Off-Nominal Procedures

The Problem

NASA's Small Aircraft Transportation System (SATS) Higher Volume Operations (HVO) Project was designed to provide a means to accommodate the anticipated 20% increase in air traffic by 2010.[1] One approach is a concept that allows pilots flying in poor weather to make decisions regarding flight path sequencing, separation, and spacing based on information displayed in the cockpit.[2] A supporting document to this paper is the normal HVO procedures paper.[3] More information can be found on NASA's web page http://ntrs.nasa.gov.

Review of HVO Normal Operations

During periods of Instrument Metrological Conditions (IMC), a block of airspace is established around the airport within which pilots will separate and space themselves from other similar SATS HVO equipped aircraft. A ground based system provides the pilots their arrival sequence. All participating aircraft within this airspace provide their own separation using a combination of procedures and specialized tools, including localized surveillance data.

HVO relies on participating aircraft to broadcast critical flight information, such as position, heading, airspeed, and projected flight path to other aircraft (e.g., ADS-B). Flight information is received by all aircraft and displayed to the pilot. The pilot's awareness of this traffic, along with HVO procedures, enables a distributed decision-making environment where the pilot maintains separation and spacing regardless of low visibility or ceilings.

The SATS HVO concept does not depend on a control tower or designated approach times but rather allows the pilot to descend and then follow the preceding aircraft on the instrument approach with appropriate spacing. The pilot uses 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 maintained throughout the approach, the pilot would begin the approach.

HVO Off-Nominal Research Conducted

HVO off-nominal procedures are similar to today's instrument flight procedures in that the pilot is expected to communicate the emergency and intention[4], has the authority to deviate from regulations for flight safety[5], and use judgment since not every off-nominal or

emergency is governed by procedures. The Airport Management Module (AMM, defined in reference 3) and HVO procedures cannot handle every conceivable emergency just as today's rules do not provide guidance for all situations, and voice communication remains key to the safe resolution of off-nominal situations in both today's and HVO's operating environments.

The SATS HVO project ended prior to completing research in this area, therefore this paper presents:

1. a comprehensive but not complete list of off-nominal HVO procedures that addresses enhanced operations, procedural deviations, equipment malfunctions, and aircraft emergencies;
2. a draft implementation that has been validated for the Pilot Cancellation of an Approach Request, and Priority Landing Request from Arriving Aircraft procedures (selected because they have a practical expectation for occurrence, stretch the concept, and may be the most difficult handle)[6];
3. and a non-validated draft implementation for the remaining identified conditions.

The development of off-nominal HVO procedures also required changes and enhancements to the original configuration of the AMM and HVO normal procedures.[7] In particular, communication equipment failure meant adding messaging hand-shake protocol to the AMM functionality and the HVO normal procedures.

Significant further development is needed for HVO off-nominal procedures, to include identifying situations or conditions requiring procedures, hazard and safety analysis, fault trees, input from a broader range of experts, and procedure validation experiments.

Finally, off-nominal procedures can be implemented in various ways. Any mention in this paper of a Pilot Advisor or Multi-Function Display (MFD) in these procedures is just one approach to implementation, and does not preclude other implementation solutions.

Off-Nominal Categories

The off-nominal conditions were categorized as: enhanced procedures (expected operations), procedural deviations (pilot error), equipment malfunctions, and aircraft emergencies.[8]

Routine Off-Nominal

- Pilot cancellation of an approach request.
- Change of approach (runway) direction.
- Pilot cancellation of a departure request.
- Leading aircraft conducting a circle-to-land.

Procedural Deviations

- Aircraft returning to the incorrect Missed Approach Holding Fix (MAHF).
- Loss of aircraft spacing on approach.
- Unable to use an assigned Initial Approach Fix (IAF) or MAHF.

Equipment Malfunctions

- Loss of aircraft state data output, arriving aircraft.
- Loss of aircraft state data output, departing aircraft.
- Loss of aircraft state data input, arriving aircraft.
- Loss of aircraft state data input, departing aircraft.
- Loss of AMM output.
- Loss of AMM reception by a single aircraft.
- Loss of aircraft voice communication capability.

Aircraft Emergencies

- Priority landing request from arriving aircraft.
- Priority landing request from departing aircraft.

Implementation Considerations

The consideration of off-nominal conditions and the development of their operational procedures have led to an incremental increase in the complexity of the normal operations. However, as in the development of the normal operations, these new procedures were based whenever possible on similar, existing procedures for off-nominal events.

Off-nominal operations, especially equipment failure detection, require system-to-system periodic checks and some data retention. These seven requirements were identified to support HVO off-nominal procedures:

1. Changes to the Self-Controlled Area (SCA) state data information.
   a. A system-to-system information exchange requires confirmation from the receiver back to the sender (e.g., AMM to the aircraft).
   b. An aircraft-to-pilot information exchange requires confirmation (e.g., the pilot responds to a change by pressing a button).
2. Periodic AMM status messages to all aircraft.
3. Periodic ADS-B messages from the AMM to participating HVO aircraft. This message is necessary to alert aircraft to their:
   a. Loss of ADS-B transmit capability
   b. Loss of the Airport Pilot Data Link Communication (APDLC) receive capability.
4. Prior to takeoff, departing HVO aircraft would require reception of both an AMM status message and an ADS-B reception message from the AMM.
5. Current SCA status information would be sent from the AMM (e.g., the number of operations and aircraft identification).

6. Participating aircraft retain sequence data from the AMM on all surrounding SCA traffic (used by pilots in situations when reversion to pilot-to-pilot procedural separation is required due to loss of aircraft state data information).
7. Periodic AMM normal operation status messages 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, an addressed datalink 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.

Routine Off-Nominal Operations

Pilot Cancellation of an Approach Request

A routine off-nominal event is for pilots to cancel their approach request and continue under VFR. This procedure would be used when weather conditions within the SCA allow for transition from IMC to Visual Metrological Conditions (VMC). This procedure was one of two selected for the HVO-Off-nominal simulation experiments conducted at NASA Langley in January 2005. The pilot workload and situation awareness results from these tests were very good, and indicated the HVO procedures as developed are safe and can be flown while in IMC (reference 6).

Actions by the pilot and AMM when canceling HVO:

1. The pilot cancels the approach (button on MFD).
2. The AMM sends cancellation notice back to the canceling aircraft.
3. If the canceling aircraft has not received an approach sequence (i.e., it was outside the SCA with a "Standby" notification):
   a. AMM deletes the aircraft from request queue.
4. If the canceling aircraft has received an approach sequence (whether inside or outside the SCA):
   a. Pilot announces cancellation over the radio.
   b. The AMM removes the canceling aircraft from the approach sequence.
   c. The AMM re-sequences the remaining aircraft to follow the aircraft canceling HVO.
   d. The AMM sends the new sequence information to all HVO aircraft.
5. The AMM marks the aircraft as non-participating. This data is passed to all aircraft for display.

Other aircraft within the SCA:

1. Each respective MFD identifies the canceling aircraft as non-participating aircraft (i.e. indicating it is not considered for the HVO arrival sequence and is not a factor for IFR clearance requirements).
2. For aircraft with an approach sequence that has been changed (re-sequenced by the AMM), the MFD notifies the pilot of changes in information (e.g., new leading aircraft and/or MAHF).
3. Each respective MFD inhibits further Pilot Advisor messages (e.g., OPEN 3000, OPEN APPROACH) until that pilot of the re-sequenced aircraft acknowledges the re-sequence.

For all procedures that require an information exchange between the pilot and the onboard system (e.g., cancellation request), an acknowledgement by the pilot is required. Similarly, information exchange between the onboard system and the AMM also requires an underlying, or system-to-system data exchange confirmation. This acknowledgement could occur via a data link "handshake" between the two systems.

Change of Approach (Runway) Direction

Who and how the active runway will be established and how that information will be disseminated has not been determined as part of this project. It could be a function of ATC, however, pilots should be able to provide feedback and input into the decision regarding the selection of the approach and the active runway.

It should also be noted that normal changes of runway landing direction should be managed prior to aircraft being assigned approach sequences. That is, ATC should inhibit arrivals until all ongoing SCA operations have been completed, holding the new arrivals above the SCA until all current SCA operations have been completed (akin to ATC procedures in radar approach environments). For those less than desirable situations where a change to the approach direction (active runway) must take place while aircraft are conducting HVO operations, the following should occur:

All pilots, ATC, and AMM involved in runway change:

1. ATC directs AMM to inhibit all new operations.
2. The AMM confirms to ATC that there are no new operations, and identifies all active HVO aircraft.
3. All landing aircraft either land or conduct a missed approach; all departing aircraft hold their position.
4. Missed approach aircraft contact ATC to obtain a clearance, preferably to the IAF of the new runway. If unable to obtain a clearance, the aircraft remains in the SCA and flies to the MAHF previously assigned by the AMM.
5. At the completion of all HVO approach operations, ATC directs the AMM to resume SCA operations.

Pilot Cancellation of a Departure Request

This condition may occur due to the pilot experiencing mechanical difficulties or being unable to depart prior to the Clearance Void Time.

The following should occur for a canceled departure:

1. Pilot Advisor alerting would be inhibited for the canceling aircraft, i.e., no OPEN DEPT message.
2. All other aircraft continue their normal operations.
3. Pilot requests a new clearance from ATC.

Leading Aircraft Conducting a Circle-to-Land

This situation could occur if the leading aircraft plans to circle to land (normally due to wind). This situation received only rudimentary attention prior to the Program ending, and further development is required.

For aircraft within the SCA:

1. Prior to departing the IAF to initiate the approach, the pilot of the leading circle-to-land aircraft broadcasts this intent to all other aircraft.
2. The following aircraft adds an additional distance or time interval to the nominal spacing value for the approach spacing.

Procedural Deviations

Aircraft Returning to the Incorrect MAHF

This procedure addresses the pilot who flies the incorrect missed approach procedure to the wrong Missed Approach Holding Fix (MAHF). Note that for a pilot to turn toward the wrong MAHF, the pilot:

- performed the wrong missed approach procedure;
- if implemented, ignored the Pilot Advisor (or Cockpit Associate, etc) alert for an incorrect missed approach procedure (text box in Fig 1);
- ignored the MAHF identified in the MFD "to waypoint" data block (text box in Figure 1);
- and ignored the missed approach procedure depicted on the MFD (dotted line in Figure 1).

Actions by the pilot who turns to the wrong MAHF:

1. Make a call over the local radio frequency announcing the problem.
2. Continue climbing along the errant missed approach path to an altitude above the SCA (due to potential loss of separation with other aircraft on the instrument approach, this aircraft must not attempt to return to the assigned MAHF).
3. Contact ATC as soon as possible and announce the problem and requests an IFR clearance from ATC (if possible, this clearance should be obtained prior to departing the SCA).

Figure 1. HVO MFD (white own-ship, traffic to follow double-blue chevron, green "Entry" message, solid line instrument approach, dotted line missed approach)

Loss of Aircraft Spacing on Approach

This procedure is for aircraft on approach that is about to lose, and will not be able to regain, spacing with the preceding aircraft. (Loss of separation while in holding or on missed approach will be examined in the next phase of research.) For loss of spacing to occur:

- the pilot did not adhere to HVO procedures (left the IAF too soon, flew too fast, etc);
- the pilot ignored, or could not resolve, cautions and warnings from onboard conflict detection software (a requirement for HVO equipage).

Trailing aircraft that will lose spacing on approach:

1. The pilot begins a climb to its missed approach altitude as required for vertical separation.
2. The pilot flies the lateral path of the approach and missed approach to the MAHF.

Unable to Use an Assigned IAF or MAHF

This condition may occur because of weather at the IAF.

Aircraft that cannot use an assigned IAF or MAHF:

1. If still in ATC managed airspace, the pilot:
   a. Coordinates with ATC to proceed to the other IAF or divert to another airport.
2. If within the SCA, the pilot:
   a. Climbs in the safest possible manner to avoid obstacles, other aircraft, and severe weather. Contact ATC prior to departing the SCA.
   b. Notifies ATC of the situation and intentions.

Equipment Malfunctions

Loss of ADS-B Output on an Arriving Aircraft

This situation occurs if an HVO aircraft loses the capability to transmit state data information via ADS-B.

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.)

1. The AMM would attempt to confirm the aircraft's ADS-B transmit capability (and all other output capabilities) prior to the sequence notification.
2. If there is no ADS-B output, the aircraft would be notified of this condition and it would be denied an approach sequence.

Aircraft With Arrival Sequence and with APDLC Output:

(The aircraft has an approach sequence and APDLC capability, but subsequently loses its ADS-B output.)

1. The AMM, noting the loss of the ADS-B signal, would inhibit all new SCA operations and set the SCA status message to no-new-operations.
2. The AMM notifies ATC that the SCA is in an inhibit status.
3. The AMM sends that aircraft a "lost ADS-B output" message that could be displayed as an alert message on the MFD. The problem aircraft transmits its position data over the APDLC.
4. The AMM resumes normal operations after the problem aircraft has landed and would also reset the SCA status to allow new operations.

Aircraft With Sequence but without APDLC Output:

(Aircraft has an approach sequence but subsequently loses both its ADS-B output and its APDLC capability.)

1. The AMM, noting the loss of an ADS-B signal from an aircraft and all other output capability, inhibits all new SCA operations and sets the SCA status message to no-new-operations.
2. The AMM notifies 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 conducting approach operations revert to procedural separation using the local radio frequency, and continue the approach operations using their original sequence assignments.
5. Departure operations would be inhibited until the aircraft with the problem lands.
6. ATC would notify the AMM that the problem aircraft has landed or departed the SCA via a ground-based message.

Loss of ADS-B or APDLC Output on Departing Aircraft

Prior to conducting an SCA departure operation, aircraft would perform an ADS-B and APDLC check with the AMM. If a successful link check can not be performed, SCA operations cannot be done by that aircraft. In this instance, this departing aircraft would be required to revert to unequipped operations.

Loss of ADS-B Input on an Arriving Aircraft

This situation would occur if an HVO aircraft has lost the capability to receive ADS-B information from other aircraft within the SCA. Several options were developed, and further effort is required to determine the most appropriate procedure.

Aircraft Without an Arrival Sequence:

1. Prior to the sequence notification, the AMM attempts to confirm the aircraft's ADS-B reception capability (and all other input capabilities).
2. If there are no ADS-B inputs to the AMM, the aircraft is denied an approach sequence.

Aircraft With Arrival Sequence and with APDLC Input:

1. The aircraft with the equipment problem would notify the AMM of the loss of ADS-B reception.
2. The aircraft with the equipment problem would use the APDLC-received state data as necessary.
3. The pilot would continue SCA operations.

Aircraft With Arrival Sequence but no APDLC Input:

1. The aircraft with the equipment failure would notify the AMM of the loss of ADS-B reception capability.
2. The AMM inhibits all new SCA operations.
3. The AMM notifies ATC that the SCA will accept no new operations.
4. The AMM would send all aircraft an "unable to receive" message, identifying the aircraft that had lost its reception capability.
5. All aircraft conducting approach operations would revert to procedural separation using voice communication and continue approach operations using their original sequence assignments.
6. The AMM would resume normal operations after the problem aircraft has landed and would reset the SCA status to allow new operations.

Loss of ADS-B or APDLC Input on Departing Aircraft

Part of the departure process is confirmation of ADS-B state data input to the requesting aircraft. The pilot must confirm the aircraft's ADS-B reception capability (and all other input capabilities). If this confirmation fails, this aircraft reverts to unequipped operations.

Loss of AMM Output

The AMM sends a periodic operational status message to ATC and to all proximate aircraft via APDLC. Loss of this operational status message indicates a failure of the AMM, and all new operations must cease.

Action by pilots and controllers:
1. ATC restricts new SCA entries and departures (ATC is informed of an AMM failure though the loss of the periodic status message).
2. Onboard aircraft systems provide notification to the pilot that the AMM has failed (identified through the loss of the AMM status message).
3. Pilots with an assigned arrival sequence use the radio to corroborate their landing sequence.
4. At the completion of all HVO operations, the airport reverts to non-HVO operations.

Loss of AMM Reception by a Single Aircraft

As noted previously, the AMM sends a periodic status message to all aircraft via the APDLC and to ATC. Loss of this operational status message indicates an APDLC receiver failure on the SATS aircraft.

Pilots operating within the SCA:
1. Pilot announces the loss of the AMM on the radio. If more than one aircraft has lost AMM reception, use the Loss of AMM Output procedure.
2. Pilots use the radio to confirm their sequence.

Loss of Voice Communications

HVO procedures were developed to accommodate the situations when aircraft lose their radio communication capability. Following normal HVO procedures assures pilots the ability to self separate within the SCA and land according to the AMM generated sequence. For aircraft in ATC airspace, traditional procedures are used in conjunction with the HVO arrival procedures.

Arriving Aircraft Outside the SCA:
1. ATC and pilots in managed airspace use traditional lost communication procedures.
2. The AMM inhibits all new operations except for the lost-communications aircraft, and sets the SCA status message to no-new-operations.
3. The lost-communications aircraft is provided with a normal, non-priority approach sequence via APDLC if all other entry constraints are met.
4. The lost-communications aircraft descends into the SCA at a time appropriate for traditional lost-communications procedures.[a]
5. ATC enables the AMM for new HVO operations after the lost communications aircraft has landed.

Arriving Aircraft Inside the SCA:
1. Normal operations continue (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).

Departing Aircraft:
1. Aircraft on the ground may not depart.
2. Departing aircraft already airborne use current IFR lost-communication procedures.

Emergency Procedures

Priority Landing Request from Arriving Aircraft

This procedure applies to aircraft that have an approach sequence and that must land immediately due to an emergency. Aircraft without an approach sequence are under ATC control and coordinate using today's procedures. This procedure was one of two selected for a simulation experiment conducted at NASA Langley in January 2005. The pilot workload, situation awareness, and usability results were very good, and indicate the procedures as developed so far are safe and can be flown while in the weather in airspace not managed by air traffic control (reference 6).

The Requesting (Emergency) Aircraft:
1. Announce the emergency and intentions via voice communication.
2. Broadcast "Emergency Landing" to the AMM and other aircraft (MFD, Cockpit Associate, etc).
3. The AMM inhibits all new SCA operations.
4. The AMM notifies ATC that the SCA status has been changed is not accepting new operations.
5. The AMM sends the identity of the priority aircraft to ATC and all other HVO aircraft.
6. The priority aircraft begins the approach as soon as possible, spacing behind the last aircraft to have already started the approach. 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.

NOTES:
- The aircraft requesting priority is not assigned an approach sequence; it is at the pilot's discretion to begin the approach (based on emergency, checklists, etc).

[a] FAR 91.185(c)(3)(i), "When the clearance limit is a fix from which an approach begins, commence descent and approach as close as possible to the expect-further-clearance time if one has been received, or if one has not been received, as close as possible to the estimated time of arrival…", FAR/AIM 2005

- If the requesting aircraft is higher at the IAF than the approach altitude, the aircraft is not expected to enter holding but begins the approach at that altitude with a normal descent (e.g., 500 foot-per-minute descent rate) after crossing the IAF.
- The pilot of the priority aircraft must request the preceding aircraft to perform a missed approach if the spacing interval becomes too close.

Other SCA Aircraft:

1. The aircraft symbol on the MFD for the priority (emergency) aircraft would be highlighted.
2. Arriving aircraft already on the approach (past the IAF) would continue with the approach. If the emergency aircraft requests that the approach path be cleared immediately for the emergency, these aircraft execute an early missed approach.
3. The AMM re-sequences aircraft for the approach retaining their relative order but excluding the priority aircraft (no re-sequence if the priority aircraft was already on the approach or was the first aircraft in holding at an IAF).
4. Onboard systems notify pilots of the new sequence.
5. Onboard systems also inhibit SCA operations messages (if implemented, e.g., Pilot Advisor OPEN 2000) until the priority aircraft has landed.
6. Once the priority aircraft has landed, normal operations resume and the AMM notifies ATC.

Priority Landing Request from a Departing Aircraft

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

Requesting Aircraft:

(The first 5 steps of this procedure are the same as for *Priority Landing Request from Arriving Aircraft*.)

1. Announce the emergency and intent over the radio.
2. Select "Emergency Landing" button on the MFD.
3. The AMM inhibits all new SCA operations.
4. The AMM notifies ATC that the SCA status has been changed to no new operations (NNO).
5. The AMM sends the identity of the priority aircraft to ATC and all other HVO aircraft.
6. The priority aircraft proceeds as soon as possible at the lowest altitude to either IAF to begin the approach, and procedurally spaces behind the last aircraft to have started the approach (if any).

NOTES:

- The requesting aircraft is not assigned an approach sequence; it is at the pilot's discretion to begin the approach (based on emergency, checklists, etc).
- If the requesting aircraft is higher at the IAF than the approach altitude, the aircraft is not expected to hold to lose altitude, but begins the approach at that altitude with a normal descent (e.g., 500 foot-per-minute descent rate) after crossing the IAF.
- The pilot of the priority aircraft must request the preceding aircraft to perform a missed approach if the spacing interval becomes too close.

Other SCA Aircraft:

1. The aircraft symbol on the MFD for the priority (emergency) aircraft would be highlighted.
2. Arriving aircraft already on the approach (past the IAF) would continue with the approach. If the emergency aircraft requests that the approach path be cleared immediately for the emergency, these aircraft execute an early missed approach.
3. Arrival aircraft holding at the IAF and 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).
4. For arrival aircraft that are holding at the IAF and are not at the lowest altitude, they are:
   a. Re-sequenced and given a "Standby".
   b. Onboard systems inhibit continuing operations Pilot Advisor messages (if implemented) until the emergency aircraft lands.
5. Normal operations are resumed once the priority aircraft has landed.

This procedure is shown in figures 2 through 5, with the example portraying the worst approach sequencing situation prior to start of this procedure. The start of "Priority Landing from a Departing Aircraft" procedure is shown in figure 2, with an aircraft on approach, three other aircraft waiting to begin the approach, and a departing aircraft with the emergency. The approach sequence numbers are shown for these aircraft.

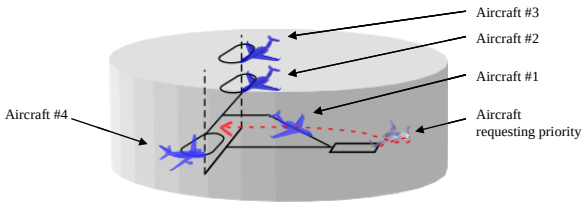

Figure 2. Departing Aircraft Priority Landing Request (1 of 4): Initial Condition, #1 on approach

Figure 3 portrays the situation immediately after the departing aircraft makes the priority request. At this point, the AMM has re-sequenced and issued new sequence numbers STANDBY notifications as appropriate. Note that the action by the AMM has affected all of the holding aircraft.

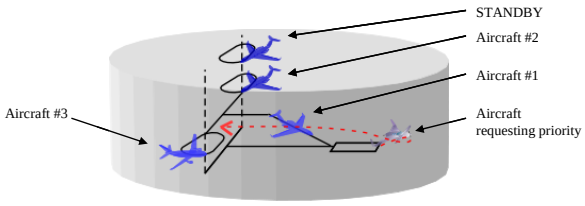

Figure 3. Departing Aircraft Priority Landing Request (2 of 4): AMM re-sequence, #2 starts approach

Figure 4 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.

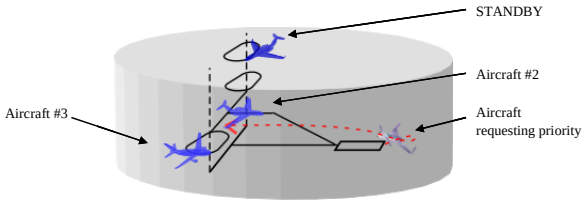

Figure 4. Departing Aircraft Priority Landing Request (3 of 4): #2 on approach, #3 ready for approach

Figure 5 shows the situation after the third aircraft begins its approach, again using its onboard tools to determine when to begin the approach.

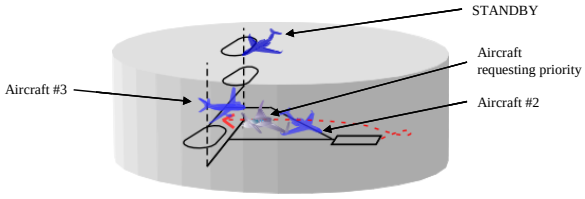

Figure 5. Departing Aircraft Priority Landing Request (4 of 4): #3 on approach, Priority ready for approach

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. 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. Once the priority aircraft has landed, the STANDBY aircraft will be allowed to resume approach operations.

Advisor Messages

In the event of any system failure that results in the aircraft reverting to procedural separation, it is envisioned that a Pilot Advisor type functionality will use the SCA status information of participating aircraft state data to assist the pilot in performing the HVO procedure. Although not required, this tool also provides assistance to the pilot in self-separation tasks, flying within a containment area along the approach path, and alerting the pilot to potential conflicts. Interactive communications between aircraft and the AMM were displayed via dynamic messaging windows to the pilot, one of which was the PA (top right of Figure 1). The PA provided procedural cues about the integrity of the pilot's flight path for the purposes of self-spacing and conflict detection and alerting .[9] This information is transformed into three types of dynamic messages used by the pilot to make decisions regarding the IFR approach: alert messages (appearance and changes in MFD information); AMM sequencing; and PA procedural cues.

Conclusion

The SATS HVO concept was expanded to include procedures for off-nominal conditions and situations. These draft procedures encompass routine enhanced operations, procedural violations, equipment failure modes, and aircraft emergencies. A range of experts developed these procedures over an eighteen month period, and two of the procedures were down-selected and tested in a simulation experiment. The results from that experiment indicate pilots were able to accommodate anomalies to normal flight without experiencing higher levels of workload or a reduction in situation awareness. Significant further work is required in the HVO off-nominal procedures area.

Operational concepts such as the one proposed in this SATS HVO off-nominal concept document, could enhance the opportunity for point-to-point air taxi or charter operations into smaller airports, providing greater convenience to the traveling public. These types of aircraft need avionics to participate that include near-term technologies like ADS-B, communications data link, and appropriate self-separation tools. The ability to operate multiple small aircraft, in near all weather conditions, at virtually any small airport, offers a unique opportunity for revolutionary transportation growth and passenger convenience.

Acknowledgments

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