



**Federal Aviation  
Administration**

**Advanced Air Mobility Initial Services  
Assessment of eVTOL Aircraft Operations  
Orlando International Airport (MCO)**

*FINAL REPORT*

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## Acronyms

Acronym	Definition
AAM	Advanced Air Mobility
AGL	Above Ground Level
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATOL	Air Traffic Operations Laboratory
ATS-TIGAR	Advanced Trajectory Services-Toolkit for Integrated Ground and Air Research
CONOPS	Concept of Operations
ERAM	En Route Automation Modernization
eVTOL	Electric Vertical Takeoff and Land
FAA	Federal Aviation Administration
FPA	Flight Path Angle
HC	Helicopter Control/Class B Control Position
HITL	Human-in-the-Loop
IFR	Instrument Flight Rules
LCE	Local Control East
LCW	Local Control West
LOA	Letter of Agreement
M&S	Modeling & Simulation
MMAC	Mike Monroney Aeronautical Center
MSL	Mean Sea Level
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NIEC	NAS Integration and Emerging Capabilities
OEM	Original Equipment Manufacturer
PDARS	Performance Data Analysis and Reporting System
RA	Resolution Advisory
RNAV	Area Navigation
RTDW	Remote Tower Display Workstation
SDRR	Simulation Driver and Radar Recorder
SME	Subject Matter Expert
STARS	Standard Terminal Automation Replacement System

TA	Traffic Alert
TCAS	Traffic Collision and Avoidance System
TGF	Target Generation Facility
TLOF	Touchdown and Liftoff
TRACON	Terminal Radar Approach Control
UTC	Universal Coordinated Time
VACE	East Vertiport
VALT	Altamonte Springs Mall Vertiport
VCAP	Cape Canaveral Vertiport
VDISN	Disney Vertiport
VFR	Visual Flight Rules
VISM	Kissimmee Gateway Airport Vertiport
VMC	Visual Meteorological Conditions
VMMH	Center Vertiport
VOCCC	Orange County Convention Center Vertiport
VORL	Orlando Executive Downtown Vertiport
VUCF	University of Central Florida/Alafaya
VUNV	Universal Studios Vertiport
VWGD	Winter Garden Vertiport
VWST	West Ramp Vertiport
WJHTC	William J. Hughes Technical Center for Advanced Aerospace

## **Executive Summary**

The Federal Aviation Administration (FAA), in collaboration with industry stakeholders, is progressing towards integrating Advanced Air Mobility (AAM), including electric Vertical Takeoff and Landing (eVTOL) aircraft, into the National Airspace System (NAS). This document describes an operational assessment concerning Orlando International Airport (MCO) to explore the impact of eVTOL operations on air traffic safety and efficiency. The assessment involved high-fidelity human-in-the-loop (HITL) simulations at the William J. Hughes Technical Center for Advanced Aerospace (WJHTC), examining proposed vertiport locations and eVTOL routes within MCO's Class B airspace. The primary objective was to evaluate the feasibility of integrating eVTOL aircraft with existing NAS operations, focusing on the implications for air traffic control and safety. The study was sponsored by the FAA and the Greater Orlando Aviation Authority (GOAA), with simulations incorporating remote capabilities from the National Aeronautics and Space Administration (NASA) and the Mike Monroney Aeronautical Center (MMAC). Through this assessment, the FAA gained important insights regarding vertiport locations, eVTOL routes, air traffic control procedures, and potential safety issues, contributing to the long-term goal of safely accommodating eVTOL operations in the NAS.

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# **1 Introduction**

Advanced Air Mobility (AAM) is a transportation system that moves people and property by air between two points using aircraft with advanced technologies, including electric aircraft, or electric Vertical Takeoff and Landing (eVTOL) aircraft, in both controlled and uncontrolled airspace. The Federal Aviation Administration (FAA) is working with its government and industry stakeholders to develop an AAM ecosystem that will enable the safe and efficient integration of AAM into the National Airspace System (NAS). The work presented here is focused on near-term implementations with piloted operations. Individual certified AAM operator initial entry into service (EIS) operations are considered building block activities. Soon, it is expected that multiple operators could be certified and have complete EIS operations and that one or more AAM key sites with multiple operators could participate. In the mature state, AAM is expected to include a mix of piloted, remotely piloted, and autonomous operations.

The document describes an operational assessment of eVTOL operations using multiple vertiport locations at Orlando International Airport (MCO). The FAA research team conducted a high-fidelity human-in-the-loop (HITL) simulation at the William J. Hughes Technical Center for Advanced Aerospace (WJHTC) NAS Integration and Evaluation Capability (NIEC) to examine how the integration of eVTOL aircraft may affect air traffic operations safety and efficiency. The simulation included proposed eVTOL routes within the MCO Class B airspace that connected proposed vertiport locations at MCO to outlying locations. The simulation gathered objective system performance data and observations from Air Traffic Control Specialists (ATCS) and pilots to identify issues that may result from the integration of eVTOL operations. The FAA and the Greater Orlando Aviation Authority (GOAA) sponsored this assessment in collaboration with the MCO Airport Traffic Control Tower (ATCT) and the Central Florida Terminal Radar Approach Control (F11 TRACON).

## **1.1 Background**

The FAA and GOAA began their examination of AAM operations at MCO by conducting a tabletop exercise in November 2024, driven by GOAA's desire to initiate AAM operations at MCO. During the tabletop exercise, participants reviewed the concept of operations for proposed central and east airfield vertiport sites along with the assumptions and methodology used for development of associated eVTOL routes. The tabletop participants reviewed preliminary eVTOL routes for both north and south flow airport operations and provided initial feedback to inform necessary revisions for scenario development.

The tabletop participants determined that eVTOL routes to the central airfield vertiport would require at least 1000' vertical separation from legacy aircraft to reduce the likelihood of wake turbulence events, safety alerts, and to protect for missed approaches and go-arounds. The participants did not think that wake turbulence would be a big concern because there was more than 3000' horizontal separation between the runways and the vertiport. However, they thought Traffic Collision and Avoidance System (TCAS) alerts may still be a concern due to legacy aircraft overtaking slower eVTOL aircraft. The participants agreed that eVTOLs should fly under the final approach fix or over the numbers (above the missed approach surface) for standardization and flexibility. They recommended that eVTOLs could cross over the runway threshold when arriving from the north or cross over the last few miles of the legacy approach when arriving from the south before turning to descend and land. The participants eliminated the use of a steep or spiraling descent eVTOL route due to anticipated demands on the aircraft. They deemed the departure routes feasible and again recommended eVTOLs fly under the final approach fix which would ensure separation with legacy aircraft. The participants also thought that departures could turn earlier after departure than shown in the proposed routes, and during low demand operations they may be able to fly directly east or west by hitting gaps in the arrival and departure flows.

For the east airfield vertiport, the participants noted that routes to the vertiport did not fly underneath legacy arrivals and departures, but they determined this was not problematic. They recommended that eVTOL arrivals crossing the airfield from the west to land on the east airfield vertiport should cross over the runway thresholds and then descend once clear. The participants also preferred departures to cross underneath legacy departures earlier than legacy arrivals due to the minimum climb rates required by departure Area Navigation (RNAV) routes which provided procedural separation.

The tabletop participants also discussed off-nominal operations including go arounds and emergency procedures. They thought the east airfield vertiport provided reasonable go around options, but the participants suggested that an alternate landing site would be needed. The central vertiport site was deemed to pose more challenges for off-nominal operations because of the limited space to maneuver between the runways and eVTOLs would likely have to fly an extended route to return to the vertiport in the event of a go around. The participants determined that an eVTOL could fly to reposition and land instead of flying a complete go around in some situations, but an alternate landing site would likely be needed.

At the conclusion of the tabletop exercise, the FAA and GOAA participants determined to update the Concept of Operations (CONOPs) and eVTOL routes. They also proposed continued

modeling and simulation of the CONOPs to include a HITL simulation to further examine the refined routes and procedures, and they added a third vertiport location on the west ramp. The eVTOL routes and procedures used in this HITL resulted directly from the tabletop exercise and subsequent discussions with GOAA, MCO, and NATCA representatives that took place prior to the HITL.

## **1.2 Objective**

The objective of this assessment was to evaluate the operational feasibility of integrating eVTOL aircraft and new eVTOL routes with existing NAS operations. The assessment implemented a high-fidelity HITL simulation to assess how the integration of eVTOL aircraft may affect the safety and efficiency of air traffic operations for north and south flow traffic at MCO. During the simulations, researchers collected objective system performance data, ATCS feedback and identified issues that may result from the integration of eVTOL operations.

## **1.3 Scope**

The scope of this assessment was limited to the Class B airspace managed by the MCO ATCT and further constrained by the chosen vertiport locations, eVTOL routes, and other potential aircraft performance characteristics.. Our primary assumptions were that vertiport sites complied with federal design standards (FAA, 2024)<sup>1</sup>, had clear approach and departure surfaces, and could support the operations simulated. Our simulation only included eVTOL aircraft operating under daytime Visual Flight Rules (VFR) with an onboard pilot. The assessment did not address specific elements including Instrument Flight Rules (IFR), land use, noise, airport planning, or other FAA regulations. The results provide initial objective and subjective data about the proposed vertiport locations, eVTOL routes, air traffic control (ATC) procedures, and ATCS workload.

## **1.4 Outcomes/Benefits**

This assessment contributed to the long-term goal of safely accommodating and integrating eVTOL aircraft operations into the NAS by providing data to support informed policy and airport development decisions.

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<sup>1</sup> The West Ramp Vertiport (VWST) was added for consideration after the November 2024 Tabletop exercise based on OEM input. It does not meet the standards of Engineering Brief (EB) 105A; rather it was modeled for the HITL under the assumption that the AAM aircraft could be handled by ATC in the same manner that they handle existing helicopter operations at MCO.

## 2 Technical Approach

The assessment took place at the WJHTC NIEC and incorporated remote simulation capabilities from the Mike Monroney Aeronautical Center (MMAC) and NASA using the NASA/FAA Laboratory Integrated Test Environment (NFLITE) (see Figure 1). NFLITE is a system of integrated laboratories located at the WJHTC and NASA Air Traffic Operations Laboratory (ATOL), built to support Urban Air Mobility (UAM) research and development. The NFLITE infrastructure contains the NIEC, eVTOL aircraft laboratories, Target Generation Facility (TGF), Standard Terminal Automation Replacement System (STARS), and En Route Automation Modernization (ERAM).

Within ERAM, a Simulation Driver and Radar Recorder (SDRR) sent simulated traffic data to the TGF. The eVTOL flight simulators also sent track data to the TGF. The TGF then sent the simulated traffic data to NASA via the FAA NAS Prototype Network (NPN) Gateway. NASA received the track data through FAA Connect and operated the Advanced Trajectory Services-Toolkit for Integrated Ground and Air Research (ATS-TIGAR) which provided eVTOL traffic and a UAM fleet operator, mission planner, and vertiport scheduler. The Simulation Manager ran the UAM Flyer which simulated eVTOL aircraft. The simulated track data from NASA was then sent back to the NPN via FAA Connect.

The FAA MMAC Airbus A330 Level D/Type 7 flight simulator was also integrated into NFLITE. The MMAC A330 flight simulator sent track data to the TGF and received all other aircraft track data for display. The NIEC provided ATCS with an out-the-window view ATCT simulator and enabled simulation pilots in the NIEC to control legacy aircraft using keyboard commands.

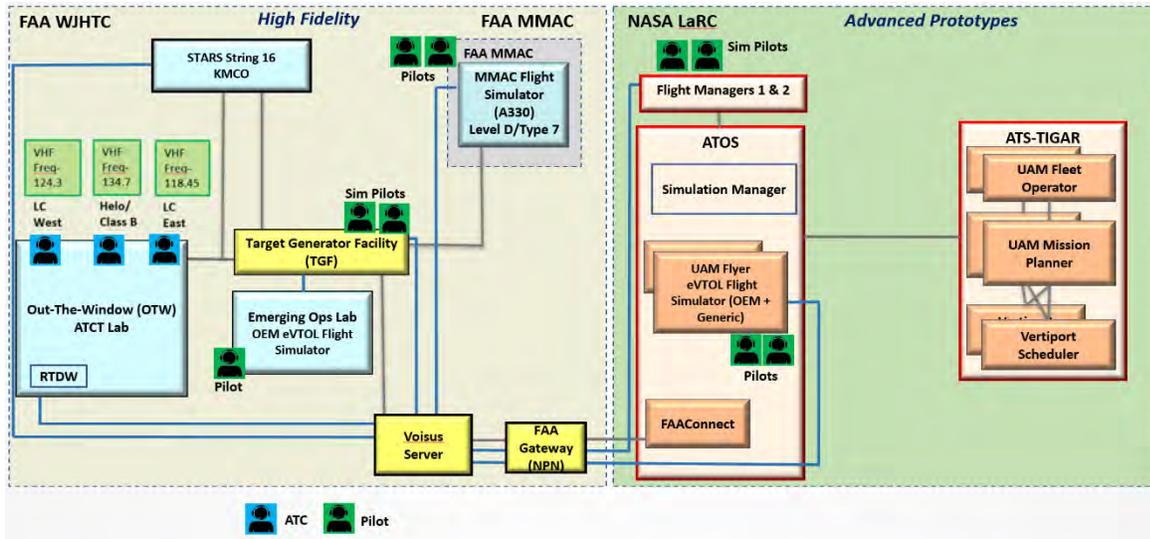


Figure 1. NASA/FAA Laboratory Integrated Test Environment (NFLITE)

In the current HITL simulation, the ATCT simulator provided participants with a simulated 270-degree out-the-window view of MCO along with three operational positions: Local Control East (LCE) managed the east runway complex (Runways 17/35), Local Control West (LCW) managed the west runway complex (Runways 18/36), and the Class B position managed all helicopter and eVTOL traffic. The ATCT simulator also provided each control position with a STARS Remote Tower Display Workstation (RTDW), ground surveillance, and communication capabilities.

## 2.1 Flight Simulators

NASA pilots used four remotely connected flight simulators to fly eVTOL aircraft using an out-the-window view along with primary flight avionics and controls. An FAA pilot flew an OEM flight simulator that was connected to the simulation in the NIEC that also had an out-the-window view, primary flight controls, and avionics. The NASA and FAA OEM flight simulators did not replicate production eVTOL aircraft but did provide realistic performance characteristics based on aircraft performance models provided by the OEMs. The simulation also included the MMAC high-fidelity, Level D aircraft simulator that emulated an Airbus A330 (A330) with TCAS technology. Two pilots flew the A330 flight simulator. All flight simulator pilots shared the same information and could see other air traffic outside their virtual windows.

## **2.2 eVTOL Aircraft Models**

There were two different OEM eVTOL aircraft models in the simulation. NASA simulation pilots controlled the flight of some eVTOL aircraft using keyboard entries and made all appropriate communications with ATC. The remaining eVTOL aircraft were flown by pilots using flight simulators. Key aircraft performance characteristics for each eVTOL model included assumptions related to passenger capacity, rotor configuration, climb and descent rates, and cruise speeds. Airspace

## **2.3 Airspace**

The HITL assessment was focused on MCO and included nearby surrounding airspace. MCO is situated in Class B airspace located to the southeast of downtown Orlando, Florida. Surrounding airports include Orlando Executive Airport (ORL) approximately 8 miles to the north and Kissimmee Gateway Airport located approximately 12 miles to the southwest. Walt Disney World Resort, with a 3-mile radius Temporary Flight Restriction, is approximately 16 miles west-southwest of MCO. The airport diagram for MCO is shown in Figure 2.



## 2.4 Air Traffic Scenarios

Three proposed vertiport locations at MCO were simulated for this study. The West Ramp Vertiport (VWST) was located on the south side of the west ramp. The Central Vertiport (VMMH) was located at the multi-modal transportation hub to the south of Terminal B and north of Terminal C. The East Vertiport (VACE) was located at the Aerospace Center of Excellence. A visual representation of the vertiport locations in relation to MCO is shown in Figure 3.

Each air traffic scenario was comprised of legacy and eVTOL aircraft. The TGF instantiated legacy aircraft, while NASA instantiated eVTOL aircraft. The background legacy air traffic was



Figure 3. MCO Vertiport Locations

based on Performance Data Analysis and Reporting System (PDARS) data and reflected the actual air traffic that occurred during that day and time. Legacy air traffic for the north flow was based on PDARS data from December 4, 2023, 1600 – 1800 Universal Coordinated Time (UTC) and included 52 arrivals and 30 departures/hr. Researchers increased the number of arrivals for the north flow legacy air traffic from 37 arrivals to 52 arrivals/hr. at the direction of ATC subject matter experts (SMEs) to generate adequate controller workload and to provide ample pressure on airport operations so that researchers could assess the potential effects of integrating eVTOL operations. The south flow legacy air traffic was based on PDARS data from December 3, 2023, 1600 – 1800 UTC and included 52 arrivals and 28 departures/hr. Like the north flow legacy air traffic scenario, researchers increased the number of arrivals from 35 to 52 to ensure adequate task load and assessment of eVTOL operations. Scenario designers also added a Medevac

helicopter flight and a general aviation pipeline inspection flight to both the north and south flow legacy air traffic scenarios based on ATC SME input so that researchers could assess the potential impacts of these flights that occur on a regular, but infrequent basis.

The eVTOL traffic added additional operations to each scenario and used a fictional vertiport network and route structure to instantiate vertiport locations outside of the Class B airspace (see Figure 4). In addition to the vertiports at MCO, the fictional vertiport network contained vertiports at Universal Studios (VUNV), University of Central Florida/Alafaya (VUCF), Orlando Executive Downtown (VORL), Disney (VDISN), Cape Canaveral (VCAP), Orange County Convention Center (VOCCC), Altamonte Springs Mall (VALT), Winter Garden (VWGD), and Kissimmee Gateway Airport (VISM). eVTOL flight plans used these vertiport locations as arrival and destination points.

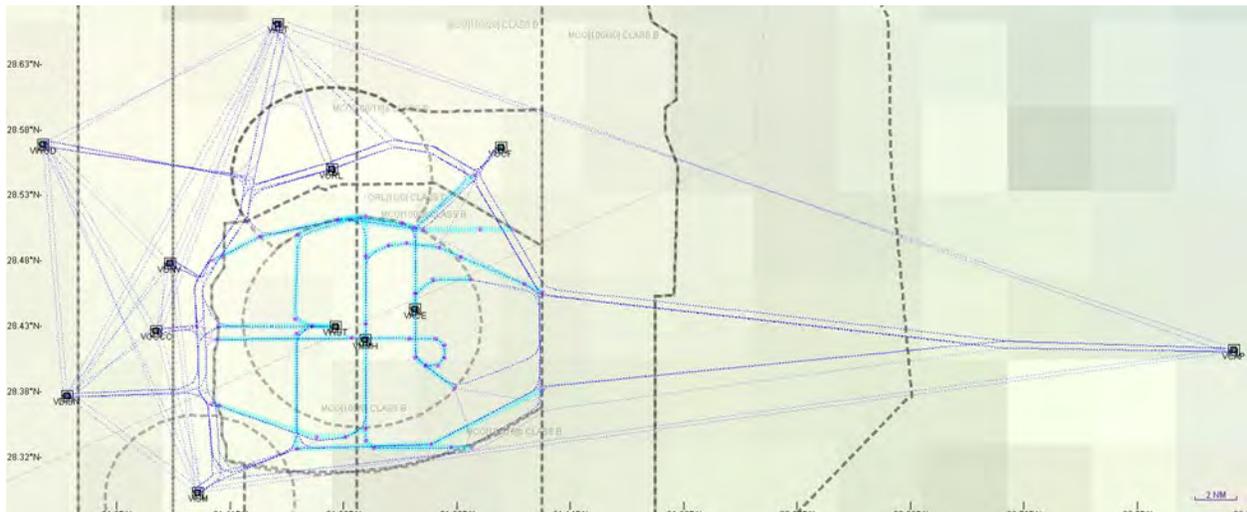


Figure 4. Fictional vertiport network of eVTOL route endpoints.

ATC SMEs that participated in the tabletop exercise and subsequent discussions designed a set of arrival and departure routes connecting the outlying vertiports to each of the vertiports located at MCO. They designed unique eVTOL arrival and departure routes to integrate eVTOL operations in the Class B airspace without impacting existing legacy operations. The eVTOL routes were initially evaluated during modeling and simulation development and revised as needed. The research team incorporated the final design of the eVTOL routes into the simulation and constructed eVTOL traffic scenarios based on those routes as described in subsequent sections. Researchers worked with ATC SMEs to create names for each of the routes to aid in the discussion and description of results. Each of the vertiports at MCO (VMMH, VACE, and

VWST) had 10 parking spots. VMMH and VACE each had two touchdown and liftoff (TLOF) areas, while VWST had one TLOF.

Scenario designers created a total of 12 scenarios comprising north and south flow legacy traffic for operations at VACE only, at VMMH only, at VWST only, and simultaneous operations at VMMH and VACE, VWST and VACE, and VMMH, VACE, and VWST operating simultaneously. The eVTOL traffic scenarios to generated 12 operations/hr. at VACE, 10 operations/hr. at VMMH, and 4 operations/hr. at VWST. The rate of operations was additive when vertiports were operating simultaneously. The following sections describe each scenario in detail.



### 2.4.2 Scenario 2 –VACE – North Flow (12 eVTOL ops/hr.)

Scenario 2 simulated eVTOL operations at VACE during north flow traffic operations (see Figure 6). eVTOL aircraft arrived from the west at 2500’ MSL on the TAFT arrival route and flew over the approach end of the runways before executing a descent to land at VACE. Arrivals also entered the Class B airspace from the southeast on the EAGLE CREEK arrival route at 1500’ MSL. eVTOLs departed VACE to the north and made an initial climb to 500’ MSL. Aircraft wishing to fly west continued northbound on the DOWNTOWN departure route before turning west just before the boundary of the Class B airspace where they flew at or below 1300’ MSL before leaving the airspace. Aircraft wishing to fly east joined the POWERPLANT departure route and then flew at or below 900’ MSL before leaving the Class B airspace.

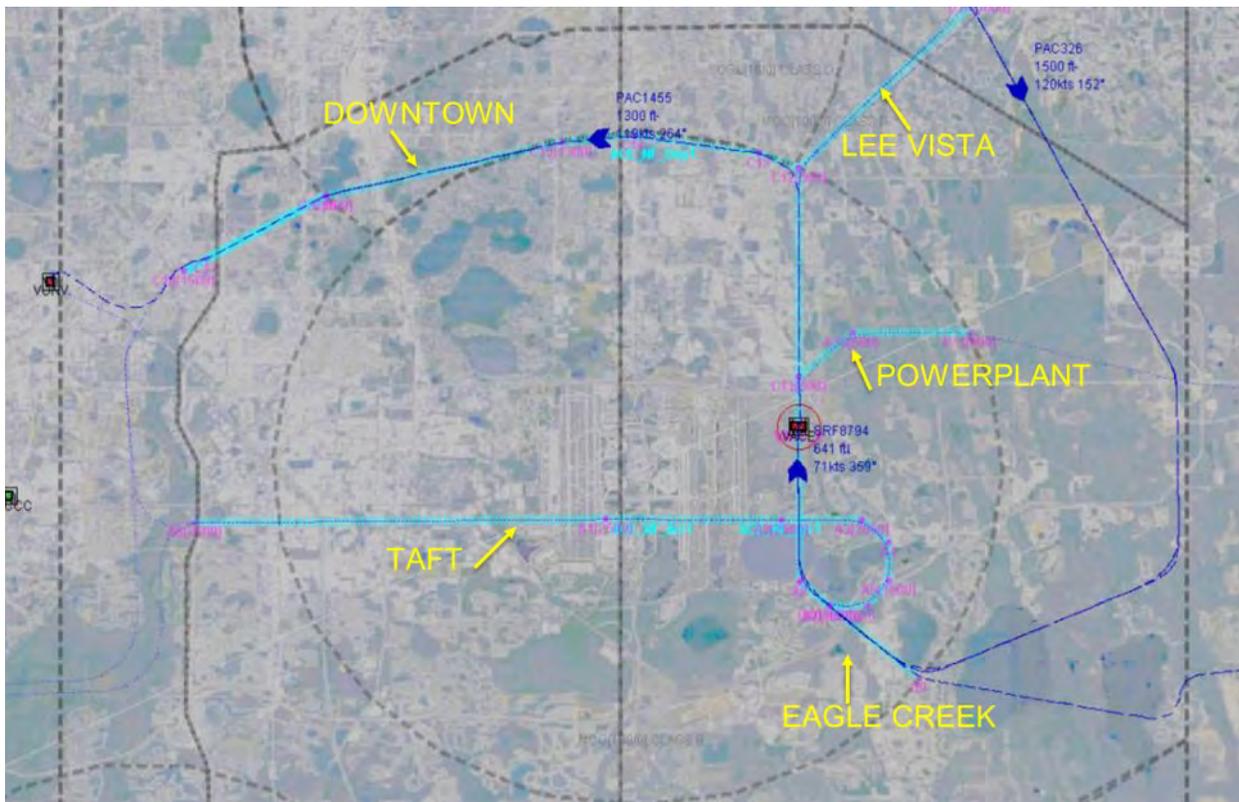


Figure 6. Scenario 2 - VACE – North Flow (12 eVTOL ops/hr.)

### 2.4.3 Scenario 3 – VMMH – South Flow (10 eVTOL ops/hr.)

Scenario 3 simulated eVTOL operations at VMMH during south flow traffic operations (see Figure 7). eVTOL arrivals to VMMH from the west approached on the SEMORAN WEST arrival route at 900’ MSL, descended to 500’ MSL to fly underneath the legacy approach to RWY 18L, and then turned south to land at the vertiport. Arrivals from the east approached on

the SEMORAN EAST arrival route at 900' MSL, descended to 500' MSL to fly underneath the legacy approach path to RWY 17R, and then turned south to land at the vertiport. eVTOL departures flew south climbing to 500' MSL and then exited the Class B airspace by turning west on the GREENWAY WEST departure route or by turning east on the GREENWAY EAST departure route. After leaving Class B airspace, eVTOLs continued their climb to 900' MSL once clear of the legacy departure path.

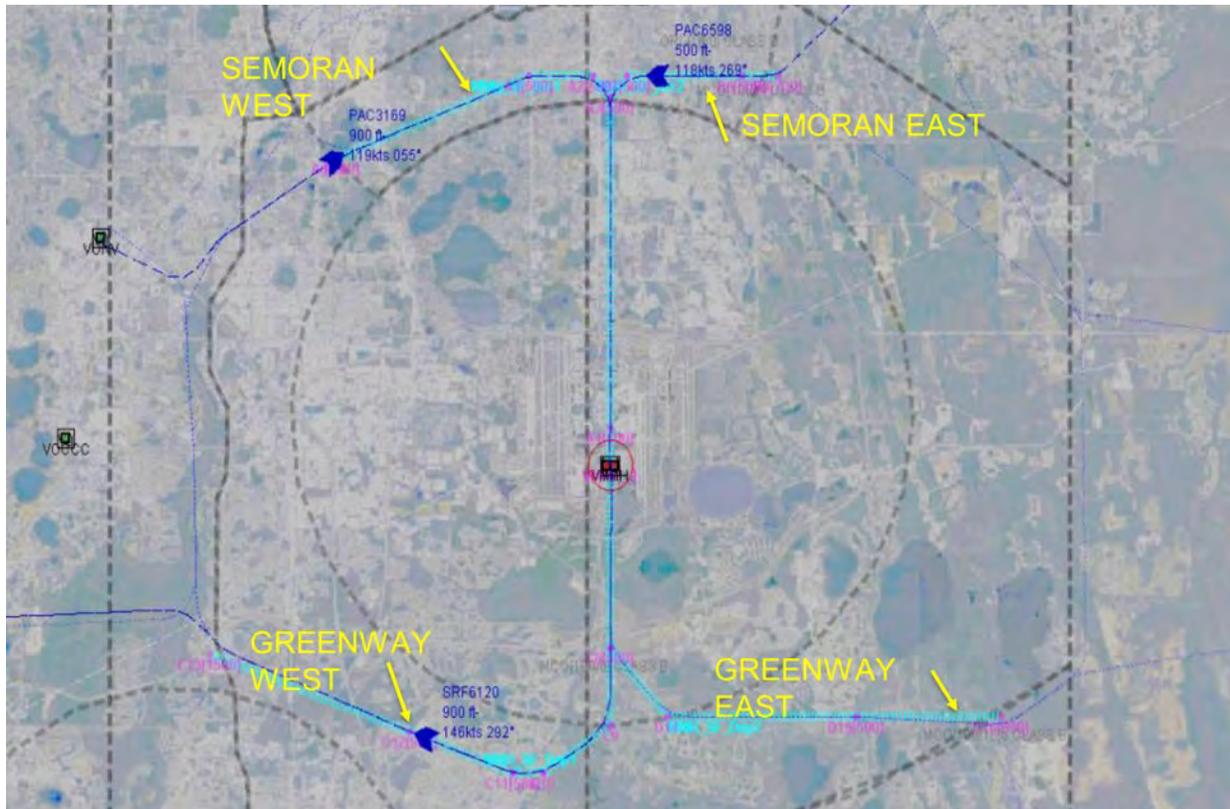


Figure 7. Scenario 3 – VMMH – South Flow (10 eVTOL ops/hr.)

#### 2.4.4 Scenario 4 – VMMH – North Flow (10 eVTOL ops/hr.)

Scenario 4 simulated eVTOL operations at VMMH during north flow traffic operations (see Figure 8). eVTOL arrivals from the west approached at 1500' MSL on the SOUTHCHASE arrival route, descended to 500' MSL, flew beneath the legacy arrival traffic to RWY 18R and then turned north to enter the Class B airspace to land at the vertiport. Arrivals from the east entered on the ST CLOUD arrival route at 900' MSL, descended to 500' MSL, flew under the legacy arrival traffic to RWY 35R, and then turned north to enter the Class B airspace and land

at the vertiport. Departures from VMMH flew north and climbed to 500' MSL until they passed under the legacy departure traffic from RWY 36L and RWY 35R. eVTOLs going west continued to climb to or below 1300' MSL, turned west on the DOWNTOWN departure route to leave the Class B airspace, and then continued to climb to 1500' MSL. eVTOLs departing to the east maintained 500' MSL and joined the BITHLO departure route to exit the Class B airspace and continue their climb to 1500' MSL.

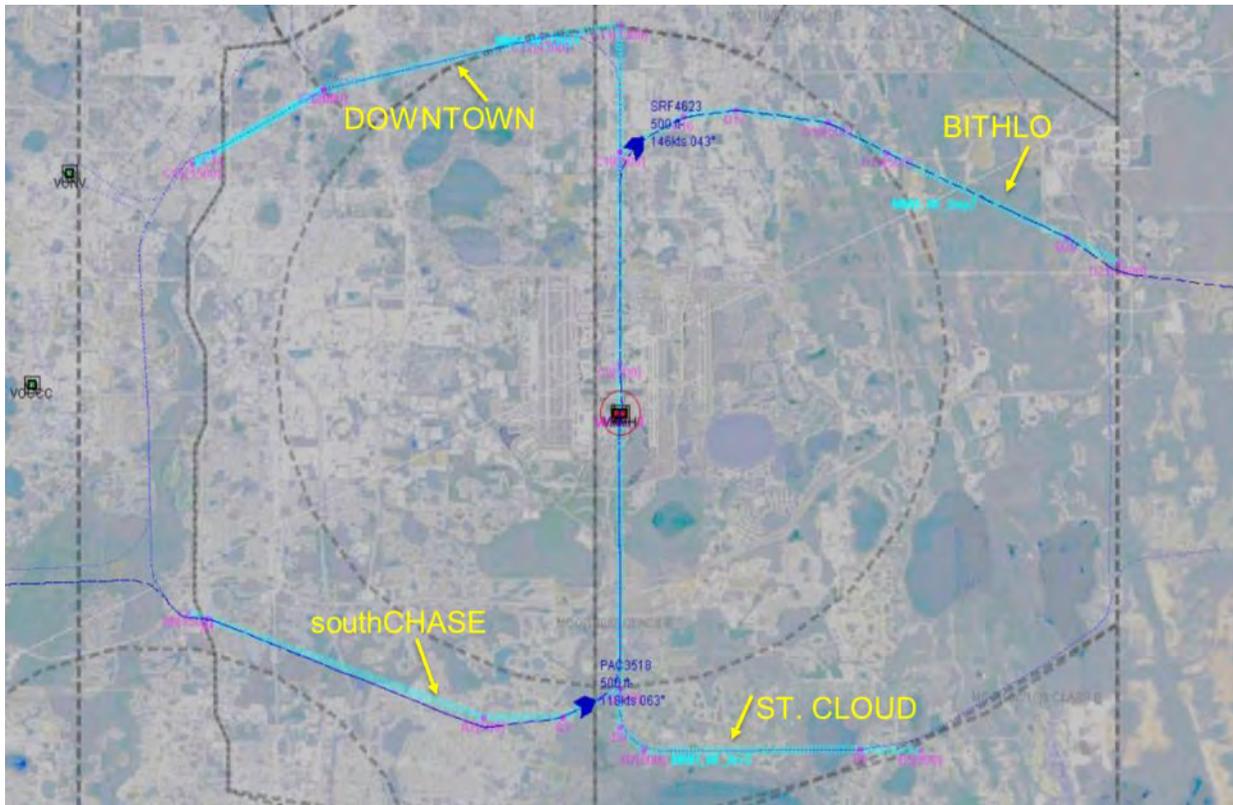


Figure 8. Scenario 4 – VMMH – North Flow (10 eVTOL ops/hr.)

#### 2.4.5 Scenario 5 – VACE and VMMH – South Flow (22 eVTOL ops/hr.)

Scenario 5 simulated combined eVTOL operations at VACE and VMMH during south flow legacy traffic operations (see Figure 9). This scenario combined the routes used for south flow scenarios where only one vertiport (VACE or VMMH) was in operation. Scenario designers did not modify any of the eVTOL arrival or departure routes for VACE or VMMH but simply added both sets of routes to the airspace so that they could operate simultaneously.

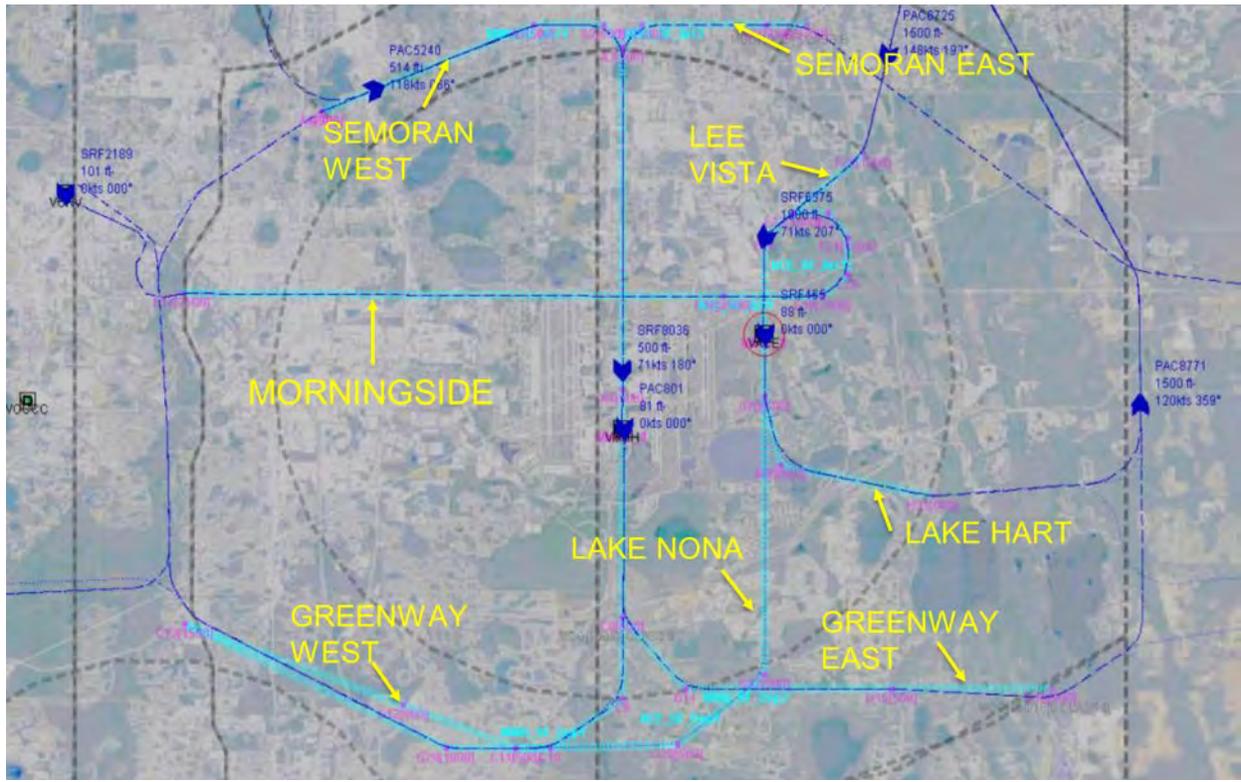


Figure 9. Scenario 5 – VACE and VMMH – South Flow (22 eVTOL ops/hr.)

### 2.4.6 Scenario 6 – VACE and VMMH – North Flow (22 eVTOL ops/hr.)

Like the previous scenario, Scenario 6 simulated combined eVTOL operations at VACE and VMMH during north flow legacy operations (see Figure 10). This scenario combined the routes used for north flow scenarios where only one vertiport (VACE or VMMH) was in operation. Scenario designers added both sets of eVTOL routes to the airspace without modifying any of the arrival or departure routes for VACE or VMMH so that both vertiports could operate simultaneously.

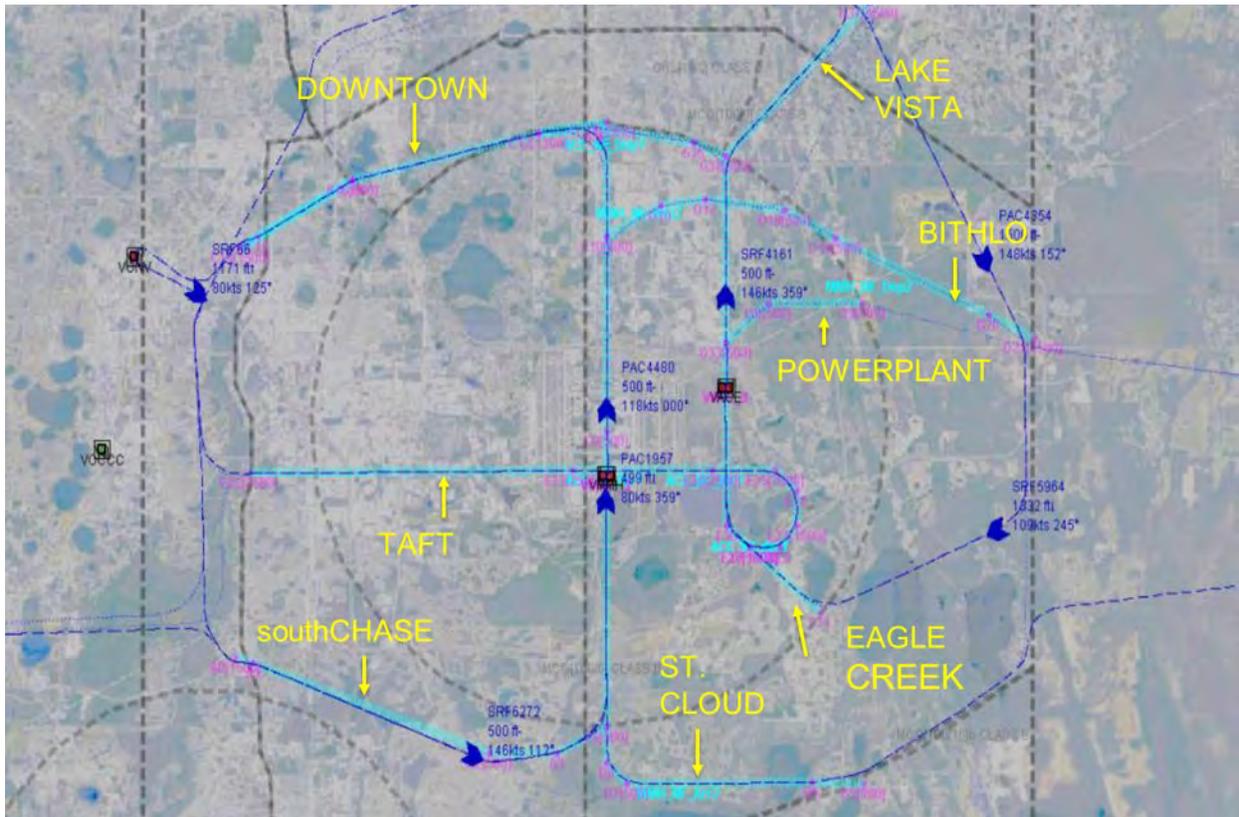


Figure 10. Scenario 6 – VACE and VMMH – North Flow (22 eVTOL ops/hr.)

### 2.4.7 Scenario 7 – VWST – South Flow (4 eVTOL ops/hr.)

Scenario 7 simulated eVTOL operations at VWST during south flow operations (see Figure 11). eVTOLs arrived from the east on the AVALON arrival route at 2500' MSL and flew over the approach end of the runways before executing a descending turn back to the east at 500' MSL and then landing at the vertiport. Arrivals also approached from the northwest on the MILLENIA arrival route at 1500' MSL, descended to 500' MSL, and then landed at the vertiport. Departures from VWST wishing to fly west departed directly to the west on the WEST departure route and climbed to 500' MSL before leaving the Class B airspace and continuing their climb to 1500' MSL. Departures wishing to fly east also departed directly to the west, climbed to 500' MSL, joined the BUENA VENTURA departure route, flew south at 500' MSL until leaving the Class B airspace, then turned east and flew under the eastbound legacy departures before continuing to climb to 1500' MSL.

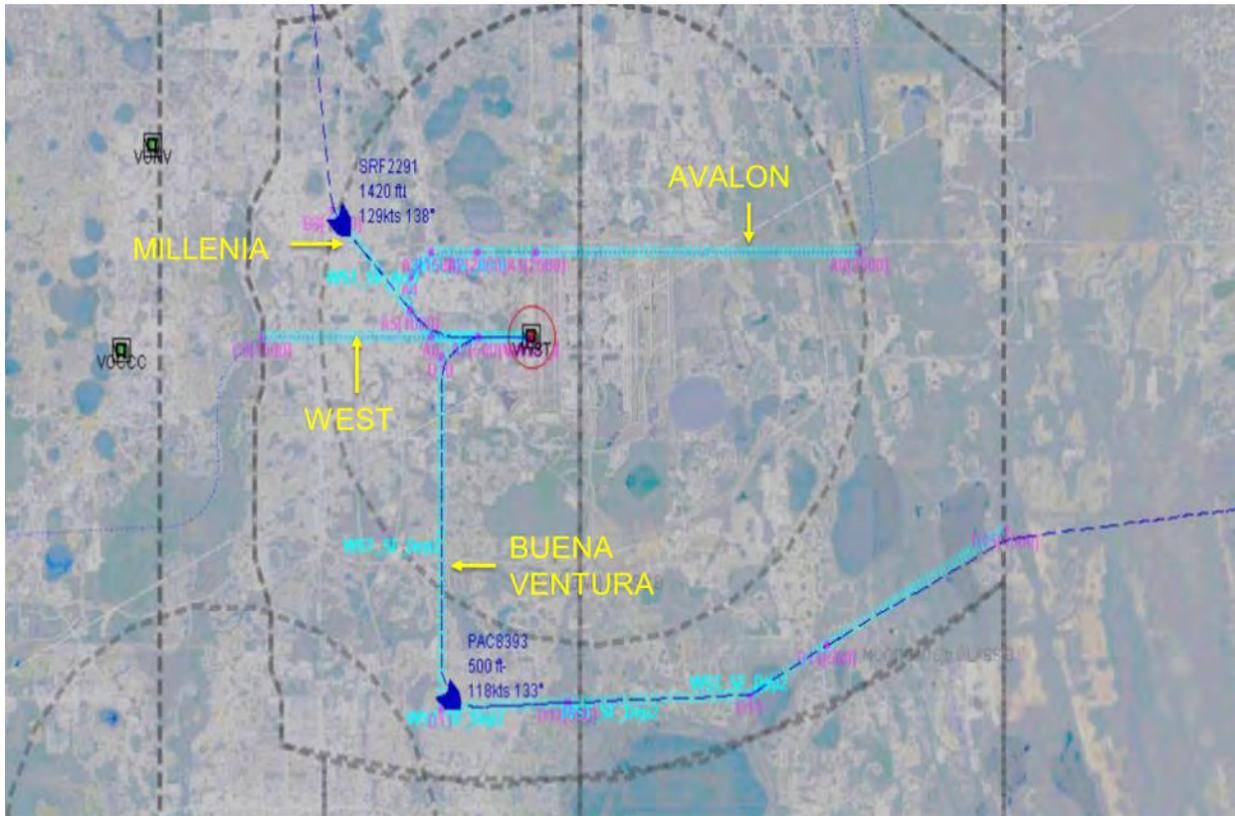


Figure 11. Scenario 7 – VWST – South Flow (4 eVTOL ops/hr.)

### 2.4.8 Scenario 8 – VWST – North Flow (4 eVTOL ops/hr.)

Scenario 8 simulated eVTOL operations at VWST during north flow operations (see Figure 12). eVTOL arrivals to VWST approached from the east on the HUNTERS CREEK arrival route at 1500' MSL before descending to 500' MSL and flying below the legacy arrival traffic and then turned north to enter the Class B airspace and land at the vertiport. Arrivals also approached from the south at 500' MSL and joined the HUNTERS CREEK arrival route before entering the Class B airspace. eVTOL departures from VWST flying west climbed to 500' MSL and followed the WEST departure route to exit the Class B airspace and continued climbing to 1500' MSL. Departures wishing to fly east departed to the west, climb to 500' MSL and turned north to follow the UCF departure route where they continued their climb to 1300' MSL and turned east along the airspace boundary to exit the Class B airspace.

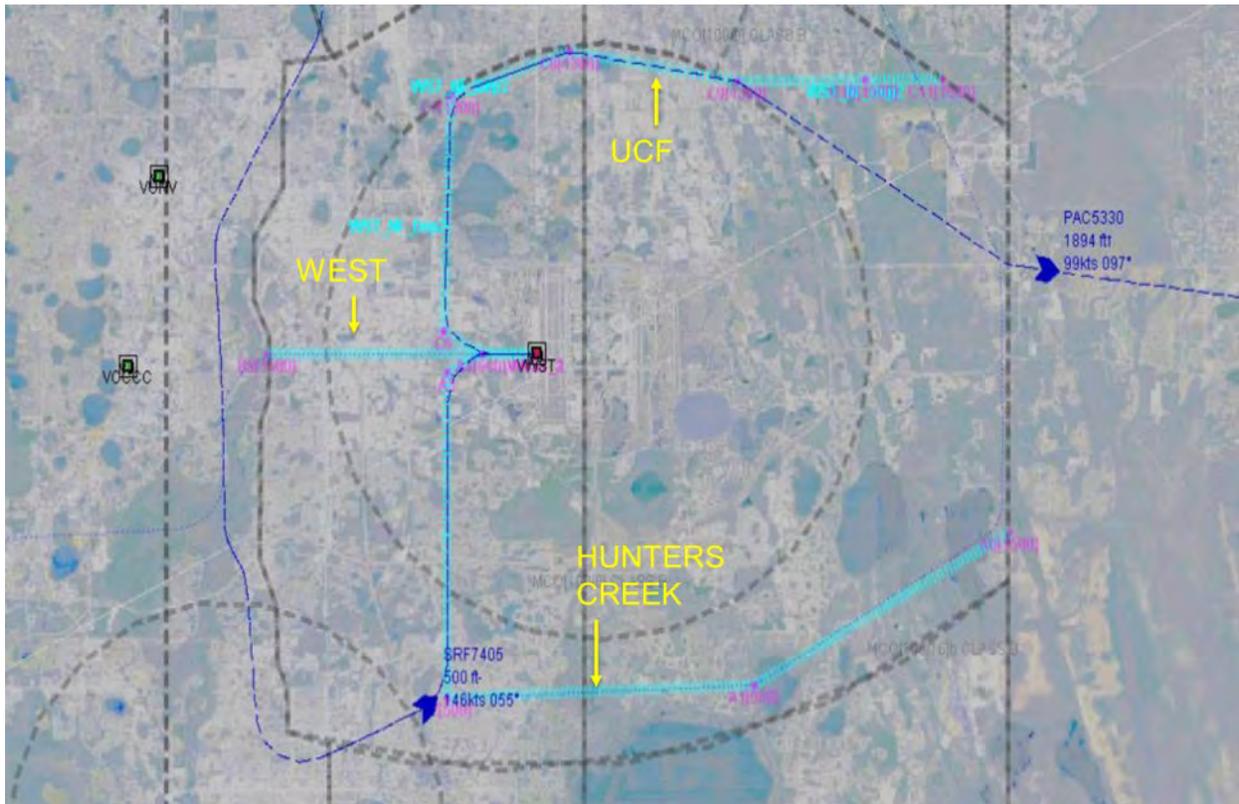


Figure 12. Scenario 8 – VWST – North Flow (4 eVTOL ops./hr.)

### 2.4.9 Scenario 9 – VWST and VACE – South Flow (16 eVTOL ops/hr.)

Scenario 9 simulated eVTOL operations at VWST and VACE during south flow operations (see Figure 13). This scenario combined the routes used for south flow scenarios where only one vertiport (VWST or VACE) was in operation (see Scenario 1, Section 2.4.1 and Scenario 7, Section 2.4.7). Scenario designers added both sets of eVTOL routes to the airspace without modifying any of the arrival or departure routes for VWST or VACE so that both vertiports could operate simultaneously.

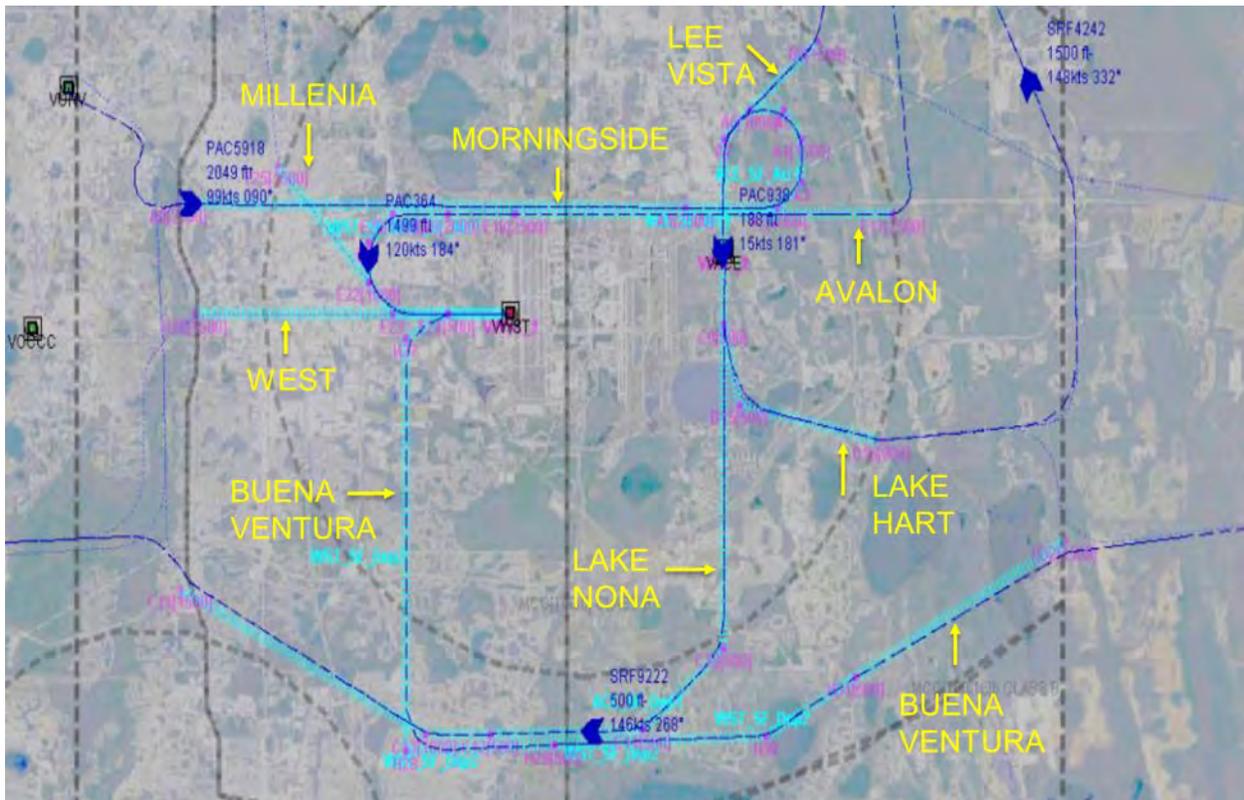


Figure 13. Scenario 9 – VWST and VACE – South Flow (16 eVTOL ops/hr.)



### 2.4.11 Scenario 11 – VWST, VMMH, and VACE – South Flow (26 eVTOL ops/hr.)

Scenario 11 simulated eVTOL operations at all three vertiport locations, VWST, VMMH, and VACE, during south flow operations (see Figure 15). This scenario combined the routes used for the south flow scenarios where only one vertiport (VWST, VMMH, or VACE) was in operation (see Scenario 7, Section 2.4.7, Scenario 3, Section 2.4.3, and Scenario 1, Section 2.4.1). Scenario designers added all three sets of eVTOL routes to the airspace without modifying any of the arrival or departure routes for VWST, VMMH, or VACE so that all three vertiports could operate simultaneously.

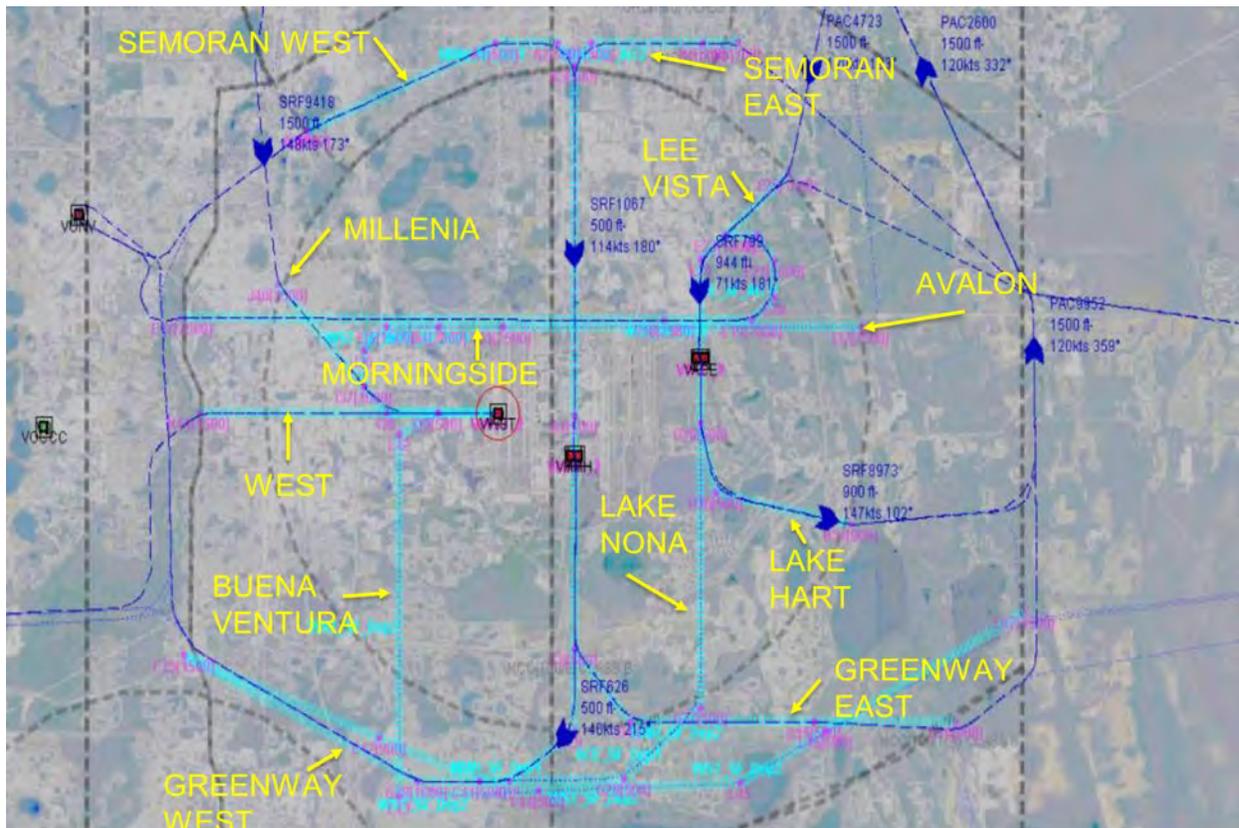


Figure 15. Scenario 11 – VWST, VMMH, and VACE – South Flow (26 eVTOL ops/hr.)

### 2.4.12 Scenario 12 – VWST, VMMH, and VACE – North Flow (26 eVTOL ops/hr.)

Scenario 12 simulated eVTOL operations at all three vertiport locations, VWST, VMMH, and VACE, during north flow operations (see Figure 16). This scenario combined the routes used for the north flow scenarios where only one vertiport (VWST, VMMH, or VACE) was in operation (see Scenario 8, section 2.4.8, Scenario 4, section 2.4.4, and Scenario 2, section 2.4.2). Scenario designers added all three sets of eVTOL routes to the airspace without modifying any of the arrival or departure routes for VWST, VMMH, or VACE so that all three vertiports could operate simultaneously.

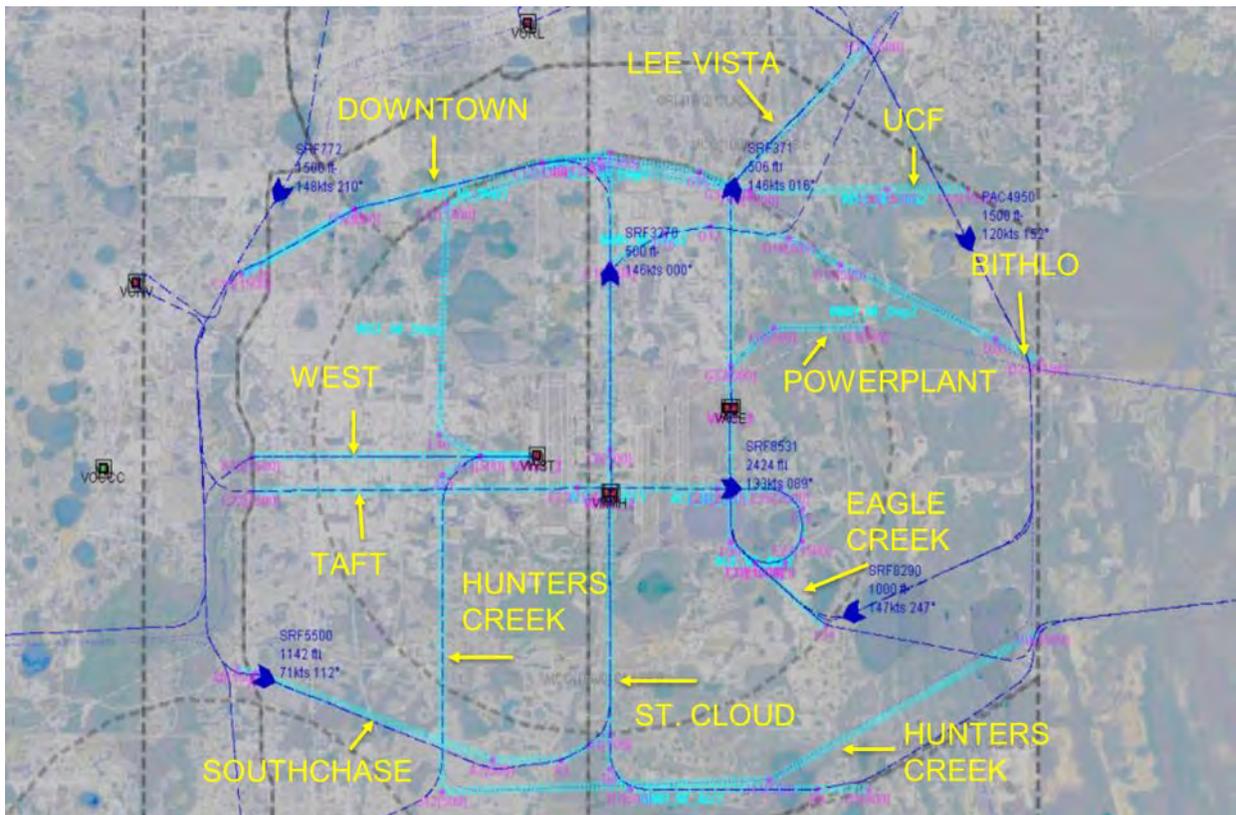


Figure 16. Scenario 12 – VWST, VMMH, and VACE – North Flow (26 eVTOL ops/hr.)

## 2.5 Pre-Testing

The research team conducted over 20 dry run and shakedown sessions to test all simulation and data collection capabilities and to refine the experimental procedure. ATC SMEs participated in the dry run and shakedown sessions and provided feedback as needed to help us improve the fidelity and overall operation of the simulation. The dry runs and shakedowns also served as an opportunity to train simulation pilots on the idiosyncrasies involved with the simulation. The dry runs relied solely on the research team, including experimenters, software and hardware engineers, pilots, and ATC SMEs. During the shakedowns, the research team systematically tested all components of the simulation including data collection and storage. The research team documented, corrected, and re-tested all issues prior to conducting the assessment.

## 3 Procedure

Participants traveled to the WJHTC on a Monday, participated in the study Tuesday-Thursday, and then returned to their facilities on Friday. Table 1 contains the planned daily schedule of events.

Table 1. Daily Schedule of Events

Tuesday		Wednesday		Thursday	
08:30-09:30	Welcome/In Brief	08:30-08:45	Review	08:30-08:45	Review
09:30-09:45	Lab Familiarization	08:45-09:30	Run 5	08:45-09:30	Run 9
09:45-10:30	Run 1	09:30-10:30	Debrief	09:30-10:30	Debrief
10:30-11:00	Debrief	10:30-10:45	Break	10:30-10:45	Break
11:00-11:15	Break	10:45-11:30	Run 6	10:45-11:30	Run 10
11:15-12:00	Run 2	11:30-12:00	Debrief	11:30-12:00	Debrief
12:00-12:30	Debrief	12:00-13:00	Lunch	12:00-13:00	Lunch
12:30-13:30	Lunch	13:00-13:45	Run 7	13:00-13:45	Run 11
13:30-14:15	Run 3	13:45-14:15	Debrief	13:45-14:15	Debrief
14:15-14:45	Debrief	14:15-14:30	Break	14:15-14:30	Break
14:45-15:00	Break	14:30-15:15	Run 8	14:30-15:15	Run 12
15:00-15:45	Run 4	15:15-15:45	Debrief	15:15-15:45	Debrief
15:45-16:15	Debrief	15:45-16:00	Recap	15:45-16:00	Recap

The participants received an in-briefing on the background and objectives of the study. ATC SMEs also provided an overview of the airspace, procedures, wake separation standards for eVTOL aircraft, and the simulated ATCT environment. The participants were instructed to control traffic as they normally would and apply existing ATC rules and procedures. An ATC SME briefed the ATCSs participants on specific information about wake turbulence separation

and reiterated wake separation rules from FAA Order JO 7110.65BB – Air Traffic Control (2025), section 5-5-4, Separation Minima, paragraph f., Wake Turbulence Application; section 3-9-7, Wake Turbulence Separation for Intersection Departures; Table 5-5-1, Wake Turbulence Separation for Directly Behind; and Table 5-5-2, Wake Turbulence Separation for On Approach. The ATC SME instructed participants that all eVTOL aircraft in the simulation were in the “small” wake category (category I) and to use current wake separation with eVTOL aircraft including 3NM when minimum reduced separation is noted, and 1,000’ vertical separation. The ATC SME also instructed ATCSs participants to use a time-based separation for arrival/departure operations within 2,500’ laterally of an active runway with 3 minutes behind a “super” category aircraft and 2 minutes behind a “heavy”, “large”, or B757 aircraft.

Prior to running each scenario, the participants received a briefing from the Principal Investigator and an ATC SME. The participants reviewed depictions of the scenario like those shown in Figures 5 - 16 to familiarize themselves before beginning each scenario. Researchers did not assign the participants to an operational control position (i.e., LCW, LCE, Class B). Instead, the participants selected which position they wanted to manage and then rotated through the positions during subsequent runs at their discretion.

The Principal Investigator determined the daily scenario run order in consultation with GOAA, NATCA, participants, and other stakeholders who were present. The scenario run order is shown in Table 2.

Table 2. Scenario Run Order

Run #	Scenario #	Vertiport(s)	Traffic Flow	eVTOL ops/hr.
1	1	VACE	South	12
2	2	VACE	North	12
3	3	VMMH	South	10
4	6	VACE, VMMH	North	22
5	4	VMMH	North	10
6	5	VACE, VMMH	South	22
7	9	VWST, VACE	South	16
8	10	VWST, VACE	North	16
9	11	VWST, VMMH, VACE	South	26
10	12	VWST, VMMH, VACE	North	26
11	11	VWST, VMMH, VACE	South	26

Based on ATC SME guidance, researchers removed 7 arrivals from the north flow and 8 arrivals from the south flow legacy air traffic during the first two runs to reduce participant task load. A data tag was also visible for each aircraft on the out-the-window display so that participants could have a chance to acclimate to the simulated ATCT environment.

The pipeline inspection flight was only present during the first six runs (Runs 1-6) and was removed for the last 5 runs (Runs 7-11) at the request of the participants. The participants considered the pipeline inspection flight to be an irregular occurrence, and they thought the first six runs proved ample opportunity to assess the potential impact this flight would have on eVTOL operations. Pilots in the MMAC A330 flight simulator flew multiple approaches during each run, noted any TCAS alerts, and executed go around procedures when instructed by ATC.

At the end of each run, the Principal Investigator gathered the participants, ATC SMEs, pilots, wake turbulence SMEs, and other stakeholders to solicit feedback on the scenario while researchers recorded notes and observations. After providing feedback, the participants took a short break of 15 to 20 minutes before starting the next run.

## **4 Results**

This section presents data for simulation operations, voice communications, wake turbulence, and summaries of the post-scenario and post-assessment feedback from the participants.

Subsequent sections present the simulation operations data for all runs and then present the voice communications data and participant feedback for each run, followed by participant feedback from the exit interview.

### **4.1 Simulation Operations**

The simulation operations data provided the run number, scenario name and duration, number of fixed wing, helicopter, and eVTOL operations, and number of arrival and departures at each runway complex (see Table 3). Except for eVTOL operations, the number of operations should not vary between runs because the north flow and south flow legacy traffic did not change between runs. The simulation operations data confirms that the simulation generated stable and desired rates of legacy and eVTOL air traffic during each run. The number of fixed wing operations in Run 1 and Run 2 was lower due to the reduced arrival rate that was implemented during the familiarization runs.

Table 3. Simulation Operations Data

Run	Scenario	Duration (H:MM:SS)	Aircraft Type			West Complex		East Complex	
			Fixed wing	Helicopter	eVTOL	Arrivals	Departures	Arrivals	Departures
1	1 - VACE south flow	0:45:28	108	4	11	18	13	16	13
2	2 - VACE north flow	0:41:00	104	4	10	19	13	18	11
3	3 - VMMH south flow	0:45:23	115	4	8	21	12	16	15
4	6 - VACE+VMMH north flow	0:50:57	118	4	20	20	15	17	11
5	4 - VMMH north flow	0:44:42	112	4	8	22	13	16	10
6	5 - VACE+VMMH south flow	0:43:27	114	4	19	23	12	20	13
7	9 - VWST+VACE south flow	0:42:48	110	3	14	21	12	18	12
8	10 - VWST+VACE north flow	0:48:50	118	3	15	23	16	17	11
9	11 - VWST+VMMH+VACE south flow	0:46:30	117	3	26	24	14	21	12
10	12 - VWST+VMMH+VACE north flow	0:48:19	119	3	26	24	15	17	11
11	11 - VWST+VMMH+VACE south flow	0:43:03	113	3	24	22	12	18	10

## 4.2 Scenario Assessments

Researchers gathered feedback from the ATCSs, pilots, and other stakeholders after each run to assess the scenario including vertiport locations, eVTOL routes, air traffic procedures, and communications. Researchers also collected voice communications data during each run to assess the number, duration, and rate of voice communication between ATCSs and pilots. Voice communications can serve as an indicator of task load and a secondary indicator of subjective workload. By measuring the voice communication between ATCSs and pilots during each run, researchers were able to assess the communication task load that was required at each ATCT operating position. The following sections present summaries of the participants' feedback and voice communications data for each of the assessment scenarios.

#### **4.2.1 Run 1 – Scenario 1 – VACE – Sout Flow (12 eVTOL ops/hr.)**

During Run 1, the ATCS participants managed air traffic in the south flow configuration with eVTOL operations only at VACE (Scenario 1; see section 2.4.1). Because this was the participants' first experience with the ATCT simulator and eVTOL operations, the research team decided to reduce the number of legacy arrivals from 52 to 44 to reduce some task load. A data tag also displayed the aircraft callsign for each aircraft in the out-the-window view to make it easier for the participants to visually acquire the aircraft as they acclimated to the simulated out-the-window view.

No issues were reported by the pilots from NASA, MMAC, or the FAA, and the ATCS participants thought that the run “went pretty smooth.” However, the ATCSs did mention some areas of concern. The eVTOL arrivals to VACE and the legacy aircraft landing on RWY 17L were likely to trigger a conflict alert that gave the ATCSs pause. The ATCSs also questioned if pilots of legacy aircraft on approach to RWY 17L may be concerned about eVTOL operations and routes to VACE. The ATCSs noted that lots of coordination was required with the LCE and LCW positions to ensure safe eVTOL operations.

One of the NASA pilots experienced an unstable approach during the run that resulted in a go around. The Class B ATCS instructed the eVTOL to turn back to the north and then re-establish the approach to land. The go around was not planned and even though it worked out well, the ATCSs noted that the Class B position is new to MCO, and the development of ATC procedures and a Letter of Agreement (LOA) would be needed to ensure they can manage eVTOL operations and potential contingencies. The ATCSs also mentioned a desire for an alternate landing area that they could use in case of emergency.

The ATCS at the Class B position had a similar level of communication task load compared to the LCE and LCW positions. All three ATCS positions had a similar number and rate of radio transmissions. However, the duration of the radio transmissions at the Class B position was relatively longer on average compared to the LCE or LCW positions. The voice communications metrics are shown in Table 4.

Table 4. Voice Communication Metrics for Run 1, Scenario 1, VACE South Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>670.71</b>	<b>200</b>	<b>3.35</b>	<b>4.40</b>
ATCS	453.75	87	5.22	1.91
TGF Pilot	13.31	5	2.66	0.11
eVTOL Flight Sim Pilot	203.65	108	1.89	2.38
<b>Local Control East</b>	<b>668.05</b>	<b>201</b>	<b>3.32</b>	<b>4.42</b>
ATCS	340.24	93	3.66	2.05
TGF Pilot	273.13	92	2.97	2.02
MMAC Flight Sim Pilot	54.68	16	3.42	0.35
<b>Local Control West</b>	<b>550.36</b>	<b>185</b>	<b>2.97</b>	<b>4.07</b>
ATCS	258.53	85	3.04	1.87
TGF Pilot	291.83	100	2.92	2.20
<b>Grand Total</b>	<b>1889.12</b>	<b>586</b>	<b>3.22</b>	<b>12.89</b>

#### 4.2.2 Run 2 – Scenario 2 – VACE – North Flow (12 eVTOL ops/hr.)

During Run 2, the ATCS participants managed air traffic in the north flow configuration with eVTOL operations only at VACE (Scenario 2; see section 2.4.2). Like Run 1, the number of legacy arrivals was reduced from 52 to 45 to reduce task load. A data tag also presented aircraft callsign for each aircraft in the out-the-window view so participants could visually acquire aircraft more easily while they acclimated to the simulated out-the-window view.

The ATCS participants quickly acclimated to the simulated ATCT environment and had few comments after the run. The ATCSs noted what they perceived as “scripted conflicts” that occurred outside of the Class B airspace, but within view on the RDTW. Regardless of actual aircraft behavior, there were no scripted conflicts in the scenarios and any conflicts outside of the Class B airspace were artifacts of scenario development and were not part of the assessment. Based on this conversation, the ATCSs again mentioned the need for procedure and LOA development to provide guidance about when to instruct aircraft to switch radio frequency and when to accept handoffs.

One of the NASA eVTOL pilots reported having to reduce speed to maintain separation from another eVTOL aircraft but did not report any other issues. The pilots in the MMAC A330 flight simulator performed multiple approaches during the run including go arounds. While climbing

out from a go around, the MMAC pilots received a TCAS traffic alert (TA) at about 1200’ above ground level (AGL). The TA was caused by an eVTOL 400’ below in straight and level flight. The TCAS TA transitioned to a resolution advisory (RA) as the A330 continued to climb.

The FAA eVTOL pilot reported that he needed to make multiple calls to request clearance to depart. The voice communication data also suggests that task load at the Class B position was relatively moderate. Based on observation, it is possible that the ATCS working the Class B position was managing other tasks and did not hear the eVTOL pilot call.

The voice communication metrics are shown in Table 5. The ATCS at the Class B position had a similar or lower level of communication task load compared to the LCE and LCW positions. The transmissions at the Class B position were similar in average duration to the LCE and LCW positions, but the rate of transmissions was relatively lower and there were fewer transmissions overall.

Table 5. Voice Communication Metrics for Run 2, Scenario 2, VACE North Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>415.77</b>	<b>131</b>	<b>3.17</b>	<b>3.20</b>
ATCS	197.37	57	3.46	1.39
TGF Pilot	125.46	32	3.92	0.78
eVTOL Flight Sim Pilot	92.94	42	2.21	1.02
<b>Local Control East</b>	<b>613.11</b>	<b>179</b>	<b>3.43</b>	<b>4.37</b>
ATCS	318.95	83	3.84	2.02
TGF Pilot	220.97	76	2.91	1.85
MMAC Flight Sim Pilot	73.19	20	3.66	0.49
<b>Local Control West</b>	<b>622.43</b>	<b>201</b>	<b>3.10</b>	<b>4.90</b>
ATCS	342.48	91	3.76	2.22
TGF Pilot	279.95	110	2.55	2.68
<b>Grand Total</b>	<b>1651.31</b>	<b>511</b>	<b>3.23</b>	<b>12.46</b>

#### 4.2.3 Run 3 – Scenario 3 – VMMH – South Flow (10 eVTOL ops/hr.)

The ATCS participants managed air traffic in the south flow configuration during Run 3 with eVTOL operations only at VMMH (Scenario 3; see section 2.4.3). The ATCSs were acclimated with the ATCT simulation environment and during this run, and all subsequent runs, and the air traffic scenarios included all legacy arrival traffic (52 arrivals/hr.) in the scenario. Furthermore, aircraft no longer had callsign data tags in the simulated out-the-window view and the ATCS

participants had to visually acquire all aircraft without the visual aids provided in Run 1 and Run 2.

At the end of the run, the ATCS participants again referred to “built-in” conflicts and wondered if there were fewer conflicts during this run. However, as previously stated, any conflicts or losses of separation that occurred outside of the Class B airspace were artifacts of the simulation and scenario design and were not part of the assessment. The ATCSs also stated that the Medevac and pipeline inspection flights in the scenario were infrequent events. They were also unsure about how to provide separation between these flights and the eVTOL aircraft. The ATCSs understood why the Medevac and pipeline inspection flights were in the scenario and recognized the potential conflicts and coordination required with eVTOL operations. However, the ATCS thought the flights became bothersome, didn’t provide any additional data to the assessment, and requested that those flights be removed from subsequent runs.

The ATCS who worked the Class B position reported that he was “locked” on the radar and was not looking out of the windows. This heads-down effect was likely caused by the difficulty of visually acquiring eVTOL aircraft from the simulated out-the-window view due to a combination of the size of the aircraft, vertiport distance from the ATCT, and limitations of the display hardware. The ATCS said he was trying to work the eVTOL traffic further away from the airport, but it was difficult because of the low aircraft conspicuity. Furthermore, the ATCS at the Class B position reported that there was no good position in the ATCT to get a good line of sight to all three vertiports at once, so it was difficult to visually scan traffic out-the-window.

The ATCSs also raised a potential issue with ORL traffic departing RWY 25 and how this traffic might interact with traffic at MCO. The simulation did not include most of the air traffic at ORL as that airspace was outside the requirements for this assessment. However, the research team did review PDARS data for MCO and ORL and determined that the eVTOL operations at MCO would not present significant issues for ORL or require additional interfacility coordination and communication.

The ATCSs and pilots emphasized the importance of clear communication and discussed the phraseology “proceed on course” vs. “proceed direct.” The pilots wanted to ensure that there was a common understanding of the phraseology and controller instructions, and in fact, there was. All the pilots and ATCSs were using the phraseology consistently and in accordance with their understanding. The FAA eVTOL and A330 pilots did not report any issues during this run. The NASA pilots noted that they flew 1200’ below legacy arrival aircraft and did not think that wake turbulence would be an issue.

A wake turbulence SME noted that legacy arrivals on RWY 17R may need some type of mitigation for eVTOL operations. Wake turbulence issues were of special concern when a heavy aircraft passed an eVTOL on approach to land. The wake turbulence SME suggested increasing eVTOL altitude from 500’ to 1000’ AGL on final approach to VMMH to shorten the approach path and reduce the risk of wake turbulence.

The voice communication metrics are shown in Table 6. The ATCS at the Class B position made fewer radio transmissions than the LCW or LCE positions, but the transmissions were longer in duration on average. Overall, the Class B ATCS spent relatively more time on the radio frequency even though he made radio transmissions at a lower rate than ATCSs at the other two positions.

Table 6. Voice Communication Metrics for Run 3, Scenario 3, VMMH South Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>646.76</b>	<b>164</b>	<b>3.94</b>	<b>3.61</b>
ATCS	403.3	74	5.45	1.63
TGF Pilot	123.61	33	3.75	0.73
eVTOL Flight Sim Pilot	119.85	57	2.10	1.26
<b>Local Control East</b>	<b>679.34</b>	<b>229</b>	<b>2.97</b>	<b>5.05</b>
ATCS	322.67	106	3.04	2.34
TGF Pilot	311.49	106	2.94	2.34
MMAC Flight Sim Pilot	45.18	17	2.66	0.37
<b>Local Control West</b>	<b>641.04</b>	<b>209</b>	<b>3.07</b>	<b>4.61</b>
ATCS	349.41	95	3.68	2.09
TGF Pilot	291.63	114	2.56	2.51
<b>Grand Total</b>	<b>1967.14</b>	<b>602</b>	<b>3.27</b>	<b>13.26</b>

#### 4.2.4 Run 4 – Scenario 6 – VACE and VMMH– North Flow (22 eVTOL ops/hr.)

The ATCSs managed air traffic in the north flow configuration during Run 4 with eVTOL operations at VACE and VMMH (Scenario 6; see section 2.4.6). This was the first run with multiple vertiports in operation. The ATCS who worked in the Class B position reported that the scenario was relatively busy because there was a lot of traffic to manage including the Medevac, pipeline inspection flight, and eVTOL aircraft.

During the run, the FAA eVTOL pilot departed from VMMH and then requested to return to the origin vertiport to accommodate a “sick passenger.” The contingency was initiated at the discretion of the Principal Investigator and ATC SMEs. The Class B ATCS instructed the

eVTOL to return to the origin vertiport and the eVTOL pilot landed without incident. The contingency revived conversation about go-around procedures. The ATCSs noted that they were unclear about eVTOL performance characteristics that may affect how they manage contingencies such as a go around where aircraft flight time and energy reserves may be relevant. The contingency operations in this scenario again highlighted the need for procedure development and training to ensure the safe integration of eVTOL operations.

The FAA eVTOL pilot departed VMMH on a subsequent flight and tested several different higher approaches to VMMH based on feedback from the wake turbulence SME after the previous run (Run 3). The FAA eVTOL pilot climbed to 2,500' MSL during the first modified approach and initiated a 7-degree descent at 80kts approximately 4 NM from VMMH. The modified approach caused a separation issue with legacy traffic on short final due to converging altitudes. During a second attempt at a modified approach, the FAA eVTOL pilot again climbed to 2,500' MSL and initiated an initial 5-degree descent at 120kts until reaching 1,500' MSL at the threshold of RWY 35L. The FAA eVTOL pilot was using the aircraft's direct-to-waypoint function and was unable to make the descent as planned due to increasing speed on the steep final approach. The FAA eVTOL pilot repeated this modified high approach a second time and the Class B ATCS provided instructions to fly a teardrop to reposition onto the vertiport. While the higher approach seemed viable with the teardrop approach, the pilot was concerned that the aggressive maneuver may affect passenger comfort.

The MMAC A330 pilots did not report any significant issues during this run. The NASA eVTOL pilots reported having to make multiple radio calls to request clearance to depart, suggesting that the ATCS working the Class B position was relatively busy attending to contingency operations tasks and multiple eVTOL aircraft approaches at VMMH.

The ATCS at the Class B position made more transmissions than the LCE and LCW positions. The transmissions made by the Class B ATCS were also longer in duration on average. The voice communication metrics show that communications task load was relatively high at the Class B position and may have been a significant contributor to overall workload at that position. The voice communication metrics are shown in Table 7.

Table 7. Voice Communication Metrics for Run 4, Scenario 6, VACE and VMMH North Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>1180.16</b>	<b>312</b>	<b>3.78</b>	<b>6.12</b>
ATCS	764.42	160	4.78	3.14
TGF Pilot	115.18	27	4.27	0.53
eVTOL Flight Sim Pilot	300.56	125	2.40	2.45
<b>Local Control East</b>	<b>704.06</b>	<b>210</b>	<b>3.35</b>	<b>4.12</b>
ATCS	334.81	93	3.60	1.83
TGF Pilot	338.18	107	3.16	2.10
MMAC Flight Sim Pilot	31.07	10	3.11	0.20
<b>Local Control West</b>	<b>637.62</b>	<b>228</b>	<b>2.80</b>	<b>4.47</b>
ATCS	319.88	104	3.08	2.04
TGF Pilot	317.74	124	2.56	2.43
<b>Grand Total</b>	<b>2521.84</b>	<b>750</b>	<b>3.36</b>	<b>14.72</b>

#### 4.2.5 Run 5 – Scenario 4 – VMMH – North Flow (10 eVTOL ops/hr.)

The ATCSs managed air traffic in the north flow configuration during Run 5 with eVTOL operations only at VMMH (Scenario 4; see section 2.4.4). At the end of this run, the ATCS reported that overtakes should not be an issue when legacy aircraft are landing on the outboard runways (RWY 36L, RWY 35R) and eVTOL aircraft are landing at VMMH. The ATCSs verified that there was also adequate lateral separation (~3,300') from the inboard runways (RWY 36R, RWY 35L), but they still had some concern about eVTOL pilots holding course in between the runway complexes. The ATCSs said that there was a lot of workload involved with making tactical decisions about spacing and merging eVTOL aircraft with legacy aircraft. The ATCSs thought that the eVTOL arrival routes to VMMH (SOUTHCHASE and ST. CLOUD) may only work with defined waypoints or some type of RNAV route that would ensure lateral spacing with legacy aircraft on final approach.

The ATCSs also requested a modification to the BITHLO eVTOL departure route going eastbound from VMMH so that it mirrors the DOWNTOWN eVTOL departure route. The ATCSs wanted BITHLO to continue further north before turning east underneath the legacy departure traffic. Keeping the eVTOL departure routes from VMMH further to the north ensured that eVTOLs could fly underneath departing legacy traffic without wake turbulence issues. Scenario designers modified the BITHLO eVTOL departure route for a subsequent run (Run 10) based on this feedback.

The FAA eVTOL pilot reported that he continued flying steeper approaches during this run but did not have any issues. The NASA eVTOL pilots did not report any issues but mentioned a situation when one of the eVTOL aircraft was at the same altitude as other legacy aircraft although there was no loss of separation. The NASA pilots were concerned that eVTOL arrivals to the south of VACE may cause TCAS alerts because they could occupy the same altitudes as legacy aircraft when flying in the opposite direction and converging on the TAFT eVTOL arrival route.

The MMAC A330 pilots reported a brief TA with an aircraft that was behind them during their climb out on a go around. However, through discussion, the participants determined that this TA was a simulation artifact and not a relevant TCAS alert.

Communication task load at the Class B position was relatively low during this run. The ATCS at the Class B position made the fewest transmissions overall and at a rate that was relatively lower than the LCE and LCW positions. Overall, the Class B radio frequency was less busy than the other radio frequencies during this run. The voice communication metrics are shown in Table 8.

Table 8. Voice Communication Metrics for Run 5, Scenario 4, VMMH North Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>482.7</b>	<b>148</b>	<b>3.26</b>	<b>3.31</b>
ATCS	269.51	72	3.74	1.61
TGF Pilot	93.92	21	4.47	0.47
eVTOL Flight Sim Pilot	119.27	55	2.17	1.23
<b>Local Control East</b>	<b>603.24</b>	<b>192</b>	<b>3.14</b>	<b>4.30</b>
ATCS	271.87	88	3.09	1.97
TGF Pilot	273.84	86	3.18	1.92
MMAC Flight Sim Pilot	57.53	18	3.20	0.40
<b>Local Control West</b>	<b>709.01</b>	<b>214</b>	<b>3.31</b>	<b>4.79</b>
ATCS	391.37	98	3.99	2.19
TGF Pilot	317.64	116	2.74	2.60
<b>Grand Total</b>	<b>1794.95</b>	<b>554</b>	<b>3.24</b>	<b>12.39</b>

#### **4.2.6 Run 6 – Scenario 5 – VACE and VMMH – South Flow (22 eVTOL ops/hr.)**

The ATCSs managed air traffic in the south flow configuration during Run 6 with eVTOL operations at VACE and VMMH (Scenario 5; see section 2.4.5). The ATCS who worked at the Class B position reported high workload during this run. Overall, the ATCSs thought the traffic was more complex, there were a lot of conflict alerts, and it “seemed like working two different VFR towers at once.” The ATCSs also reported that VACE, which is about 2.5 miles from the ATCT, was difficult to see and it was difficult to determine if an eVTOL aircraft was occupying the TLOF or not. The ATCSs said the difficulty with visually acquiring eVTOL aircraft in the out-the-window view made them feel like they were working a radar position because the only way they could get position information about eVTOL aircraft was from the RTDW.

In addition to the perceived traffic complexity and difficulty seeing eVTOL aircraft, there were simulation issues during this run that resulted in some aircraft not automatically acquiring a data tag. The ATCSs had to manually place data tags on some aircraft during this run, and this contributed to their task load and reduced ability to manage air traffic further away from the airport.

Although the research team provided the ATCSs with lists of arrival and departure aircraft, the ATCSs said that they would have paper or electronic flight progress strips in the real world that would provide them with additional information and help them manage each flight. All the participants discussed whether eVTOL flights would file VFR or IFR flight plans and the fact that VFR flight plans do not propagate into the NAS. To generate a flight progress strip for a VFR flight plan, the FAA would need to implement stereo flight plans, create local adaptations for eVTOL aircraft, coordinate with clearance delivery, or the ATCSs would need to enter the flight plan for each flight. The participants also discussed the possibility of a “mobile” clearance in the future but concluded that a flight strip printer may be needed at the Class B position in the interim, especially if the operational tempo increases and manual processes become burdensome.

In addition to procedures, the ATCSs also discussed the eVTOL routes and their effect on the legacy traffic. The ATCSs were especially concerned about the MORNINGSIDE eVTOL arrival route to VACE. The ATCSs said that the MORNINGSIDE route had the potential to create nuisance traffic alerts and unease among legacy aircraft pilots when eVTOL aircraft made their turning descent to final approach. They recommended modifying the MORNINGSIDE route to implement a teardrop pattern for the turn and descent that would extend the route further away from legacy arrivals on RWY 17L. Scenario designers implemented the teardrop pattern on the MORNINGSIDE eVTOL arrival route for a subsequent run (Run 11; see section 4.2.11) so that it could be assessed by the ATCSs and eVTOL aircraft pilots.

The FAA eVTOL pilot flew two different approaches to VMMH during this run. He flew a normal approach on the first flight and then flew a high approach on the second flight. The participants noted that the normal (lower) approach worked well with outboard arrivals. They said the higher approach worked better with inboard arrivals because it mitigated issues with wake turbulence when legacy aircraft overtake eVTOL aircraft on final approach, but the ATCSs preferred the normal approach for the current operation. Once again, the ATCSs recognized their concern with eVTOL aircraft flying in between the runway complexes and the possible need for more precise navigation provided by waypoints within an LOA or some type of RNAV route.

The MMAC A330 pilots did not report any issues during this run, but the NASA eVTOL pilots questioned the procedure for entering Class B airspace. One of the NASA eVTOL pilots wondered if the TRACON ATCS would provide clearance to enter the Class B airspace. However, during the design of the HITL simulation, the ATC SMEs agreed that clearance to enter Class B airspace would be given by a ATCT ATCS. The questions about pilot and ATCS communication again highlight the need for the FAA to review procedures and phraseology involving eVTOL operations and document them in the appropriate orders and LOAs.

The ATCSs made and received a similar number of radio transmissions at all three positions during this run. The ATCSs also made radio transmissions at about the same rate. However, the ATCS at the Class B position made transmissions that were relatively longer on average than the radio transmissions ATCSs made at the LCE or LCW positions. The voice communication metrics are shown in Table 9.

Table 9. Voice Communication Metrics for Run 6, Scenario 5, VACE and VMMH South Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>808.81</b>	<b>199</b>	<b>4.06</b>	<b>4.58</b>
ATCS	504.13	91	5.54	2.09
TGF Pilot	29.07	6	4.85	0.14
eVTOL Flight Sim Pilot	275.61	102	2.70	2.35
<b>Local Control East</b>	<b>719.5</b>	<b>228</b>	<b>3.16</b>	<b>5.25</b>
ATCS	384.18	117	3.28	2.69
TGF Pilot	288.61	97	2.98	2.23
MMAC Flight Sim Pilot	46.71	14	3.34	0.32
<b>Local Control West</b>	<b>565.06</b>	<b>203</b>	<b>2.78</b>	<b>4.67</b>
ATCS	244.75	91	2.69	2.09
TGF Pilot	320.31	112	2.86	2.58
<b>Grand Total</b>	<b>2093.37</b>	<b>630</b>	<b>3.32</b>	<b>14.50</b>

#### 4.2.7 Run 7 – Scenario 9 – VWST – VACE - South Flow (16 eVTOL ops/hr.)

During Run 7, the ATCSs managed air traffic in the south flow configuration with eVTOL operations at VWST and VACE (Scenario 9; see section 2.4.9). None of the participants reported any issues during this run as the ATCSs and pilots were able to manage eVTOL operations relatively easily.

The ATCSs made and received a similar number of radio transmissions at all three positions during this run. The ATCS at the LCW position had the highest number of radio communications overall. The ATCS at the Class B position made relatively fewer radio transmissions than the other two ATCS positions, but those transmissions tended to be relatively longer in duration on average. The voice communication metrics are shown in Table 10.

Table 10. Voice Communication Metrics for Run 7, Scenario 9, VWST and VACE South Flow

Comm Position	Duration (sec)	Number	Average Duration (sec)	Tx/min
<b>Class B</b>	<b>588.5</b>	<b>175</b>	<b>3.36</b>	<b>4.09</b>
ATCS	338.17	67	5.05	1.57
TGF Pilot	37.93	10	3.79	0.23
eVTOL Flight Sim Pilot	212.4	98	2.17	2.29
<b>Local Control East</b>	<b>598.69</b>	<b>175</b>	<b>3.42</b>	<b>4.09</b>
ATCS	291.04	79	3.68	1.85
TGF Pilot	257.92	83	3.11	1.94
MMAC Flight Sim Pilot	49.73	13	3.83	0.30
<b>Local Control West</b>	<b>527.78</b>	<b>191</b>	<b>2.76</b>	<b>4.46</b>
ATCS	220.89	84	2.63	1.96
TGF Pilot	306.89	107	2.87	2.50
<b>Grand Total</b>	<b>1714.97</b>	<b>541</b>	<b>3.17</b>	<b>12.64</b>

#### 4.2.8 Run 8 – Scenario 10 – VWST and VACE – North Flow (16 eVTOL ops/hr.)

The ATCSs managed air traffic in the north flow configuration during Run 8 with eVTOL operations at VWST and VACE (Scenario 10; see section 2.4.10). Based on feedback from the ATCSs after Run 2 (Scenario 2; see section 2.4.2), the NASA eVTOL pilots attempted to fly a teardrop approach that extended their flight path further to the east before turning back west to land at VACE. This modified TAFT eVTOL arrival route took the aircraft further away from legacy operations landing on RWY 17L.

The ATCSs reported that the modified TAFT eVTOL arrival route and approach to VACE worked better than the original turning descent to the south, and they did not have to issue traffic alerts with the modified route because eVTOL operations were separated further from legacy aircraft. The ATCSs had some concern about eVTOL departures from VWST that flew at about 1300' MSL from east to west on the UCF eVTOL departure route and whether they would be far enough below the legacy departures including departures at ORL. After discussion, the participants agreed that the currently designed eVTOL routes would provide adequate separation from legacy aircraft.

The NASA eVTOL pilots flew multiple operations to VACE and reported that the modified TAFT eVTOL arrival route worked well. The NASA eVTOL pilots also thought that the modified route provided more opportunity for lower performance eVTOL aircraft that may have lower rates of descent to use VACE. The research team determined to formally implement the modified TAFT eVTOL arrival route in a subsequent run the next day. The MMAC A330 pilots and the FAA eVTOL pilot did not report any issues during this run.

The ATCS at the Class B position had relatively fewer voice communications overall and made almost half as many radio transmissions during this run than either the LCW or LCE positions. The duration of radio transmissions made by the Class B ATCS was about the same or lower on average than the LCW or LCE positions. The voice communication metrics are shown in Table 11.

Table 11. Voice Communication Metrics for Run 8, Scenario 10, VWST and VACE North Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>409.11</b>	<b>141</b>	<b>2.90</b>	<b>2.89</b>
ATCS	182.87	56	3.27	1.15
TGF Pilot	41.2	8	5.15	0.16
eVTOL Flight Sim Pilot	185.02	77	2.40	1.58
<b>Local Control East</b>	<b>674.9</b>	<b>195</b>	<b>3.46</b>	<b>3.99</b>
ATCS	330.32	90	3.67	1.84
TGF Pilot	300.55	93	3.23	1.90
MMAC Flight Sim Pilot	44.03	12	3.67	0.25
<b>Local Control West</b>	<b>759.51</b>	<b>240</b>	<b>3.16</b>	<b>4.91</b>
ATCS	382.38	108	3.54	2.21
TGF Pilot	377.13	132	2.86	2.70
<b>Grand Total</b>	<b>1843.52</b>	<b>576</b>	<b>3.20</b>	<b>11.80</b>

#### **4.2.9 Run 9 – Scenario 11 – VWST, VMMH, and VACE – South Flow (26 eVTOL ops/hr.)**

During Run 9, the ATCSs managed air traffic in the south flow configuration with eVTOL operations at VWST, VMMH, and VACE (Scenario 11; see section 2.4.11). The ATCSs reported that conflict alerts occurred frequently, but operations on the west side of the airport were smooth. The ATCSs were concerned about spacing between legacy aircraft departing RWY 17R and eVTOL aircraft departing VACE. The ATCSs suggested that eVTOL aircraft departing VACE should turn to a 120-degree heading and then go east so that they move away from the departing legacy traffic as soon as possible.

The NASA eVTOL pilots did not report any issues during this run. However, based on feedback from a previous run (Run 6, Scenario 5; see section 4.2.6), the NASA eVTOL pilot flew a modified teardrop arrival route to VACE. The modified MORNINGSIDE eVTOL arrival route extended the downwind leg and took the aircraft further to the east without leaving the Class B airspace before turning back west to land at VACE. The NASA pilot reported that the modified route worked well, and the participants agreed to formally implement the modified MORNINGSIDE eVTOL arrival route in a subsequent run the next day. Neither the MMAC A330 pilots nor the FAA eVTOL pilot reported any issues during the run.

The communication task load for the Class B position appeared to be relatively higher on average during the run compared to the other ATCS positions. The ATCS at the Class B position received more voice communications, made more voice transmissions, and had longer voice transmissions than either the LCW or LCE positions. The relatively higher level of communication task load at the Class B position may be attributed in part to the volume of eVTOL operations during the run and the fact that the ATCS managed eVTOL operations at three different vertiports. The voice communication metrics for the run are shown in Table 12.

Table 12. Voice Communication Metrics for Run 9, Scenario 11, VWST, VMMH, and VACE South Flow

Comm Position	Duration (sec)	Number	Average Duration (sec)	Tx/min
<b>Class B</b>	<b>882.08</b>	<b>261</b>	<b>3.38</b>	<b>5.61</b>
ATCS	492.96	103	4.79	2.22
TGF Pilot	39.47	9	4.39	0.19
eVTOL Flight Sim Pilot	349.65	149	2.35	3.20
<b>Local Control East</b>	<b>573.44</b>	<b>187</b>	<b>3.07</b>	<b>4.02</b>
ATCS	257.4	86	2.99	1.85
TGF Pilot	261.5	85	3.08	1.83
MMAC Flight Sim Pilot	54.54	16	3.41	0.34
<b>Local Control West</b>	<b>532.38</b>	<b>184</b>	<b>2.89</b>	<b>3.96</b>
ATCS	213.75	79	2.71	1.70
TGF Pilot	318.63	105	3.03	2.26
<b>Grand Total</b>	<b>1987.9</b>	<b>632</b>	<b>3.15</b>	<b>13.59</b>

#### 4.2.10 Run 10 – Scenario 12 – VWST, VMMH, and VACE – North Flow (26 eVTOL ops/hr.)

The ATCSs managed air traffic in the north flow configuration with eVTOL operations at VWST, VMMH, and VACE (Scenario 12; see section 2.4.12). As a result of discussions from the previous run (Run 9, Scenario 11; see section 4.2.9) scenario designers modified the TAFT eVTOL arrival route to VACE (see Figure 17) during this run. This modified route required eVTOL aircraft landing at VACE to fly further to the east before turning back to the west and entering at a 45-degree angle approach to merge with the EAGLE CREEK eVTOL arrival route and the VACE final approach. Based on discussions from Run 5, Scenario 4 (see section 4.2.5), scenario designers also modified the BITHLO eVTOL departure route from VMMH to mirror the DOWNTOWN eVTOL departure route (see Figure 18). The modified BITHLO departure route required eVTOL aircraft to turn to the east later and ensured adequate vertical separation from legacy departures. All other eVTOL routes were unchanged.

The ATCSs reported that the modified TAFT and BITHLO eVTOL routes worked well and there were no specific concerns from the ATCS who worked at the Class B position. One of the ATCS thought that the modified TAFT eVTOL arrival route was located too far north and suggested that the route pass over the lake. Moving the TAFT eVTOL arrival route further south would ensure better separation between eVTOL aircraft and arriving legacy aircraft and eVTOLs aircraft could turn back to the northwest to cutoff the “trombone” path and go direct to VACE.

The NASA eVTOL pilots agreed that moving the TAFT eVTOL arrival route further south was preferred because an early descent on the westbound leg of the “trombone” may conflict with obstructions (i.e., antenna) and the tight turn required the pilot to reduce airspeed before descending, thereby making the approach less efficient. Neither the MMAC A330 pilots nor the FAA eVTOL pilot reported any issues.



Figure 17. Modified TAFT eVTOL arrival route to VACE in north flow configuration

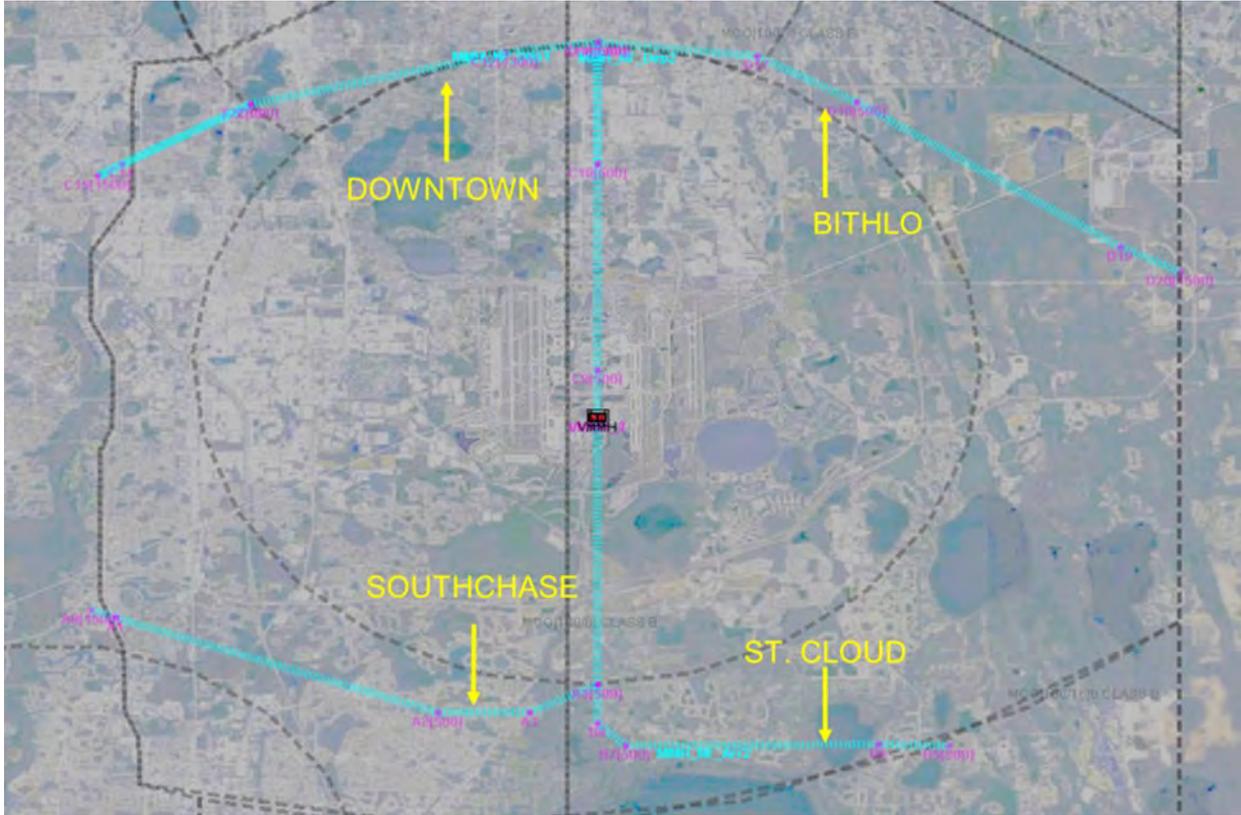


Figure 18. Modified BITHLO eVTOL departure route from VMMH in north flow configuration

The ATCS at the Class B position made a moderate number of radio transmissions compared to the LCW and LCE positions. However, the ATCS at the Class B position managed relatively more voice communications overall. Voice communications both made and received by the ATCS at the Class B position were also longer on average compared to the LCW and LCE positions suggesting that communications with the eVTOL pilots generated notable task load during this run. The voice communication metrics are shown in Table 13.

Table 13. Voice Communication Metrics for Run 10, Scenario 12, VWST, VMMH, and VACE North Flow

Comm Position	Duration (sec)	Number	Average Duration (sec)	Tx/min
<b>Class B</b>	<b>801.57</b>	<b>241</b>	<b>3.33</b>	<b>4.99</b>
ATCS	412.04	90	4.58	1.86
TGF Pilot	40.29	9	4.48	0.19
eVTOL Flight Sim Pilot	349.24	142	2.46	2.94
<b>Local Control East</b>	<b>541.49</b>	<b>184</b>	<b>2.94</b>	<b>3.81</b>
ATCS	219.09	79	2.77	1.64
TGF Pilot	270.99	92	2.95	1.90
MMAC Flight Sim Pilot	51.41	13	3.95	0.27
<b>Local Control West</b>	<b>627.01</b>	<b>216</b>	<b>2.90</b>	<b>4.47</b>
ATCS	296.9	102	2.91	2.11
TGF Pilot	330.11	114	2.90	2.36
<b>Grand Total</b>	<b>1970.07</b>	<b>641</b>	<b>3.07</b>	<b>13.27</b>

#### 4.2.11 Run 11 – Scenario 11 – VWST, VMMH, and VACE – South Flow (26 eVTOL ops/hr.)

The ATCSs managed air traffic in the south flow configuration with eVTOL operations at VWST, VMMH, and VACE (Scenario 11; see section 2.4.11) during this run. The Principal Investigator consulted with GOAA, NATCA, participants, and other stakeholders present, and determined to repeat Scenario 11 during this run using the modified MORNINGSIDE eVTOL arrival route to VACE. Based on discussions after a previous run (Run 6, Scenario 5; see section 4.2.6) and a previous attempt by the NASA eVTOL pilots to fly a modified arrival route to VACE (Run 9, Scenario 11; see section 4.2.9), scenario designers formally implemented the modified MORNINGSIDE eVTOL arrival route to VACE (see Figure 19). The modified MORNINGSIDE route extended the downwind leg and took the aircraft further to the east without leaving the Class B airspace before turning back west to land at VACE. All other eVTOL routes to and from VWST, VMMH, and VACE remained unchanged as shown in Figure 15.

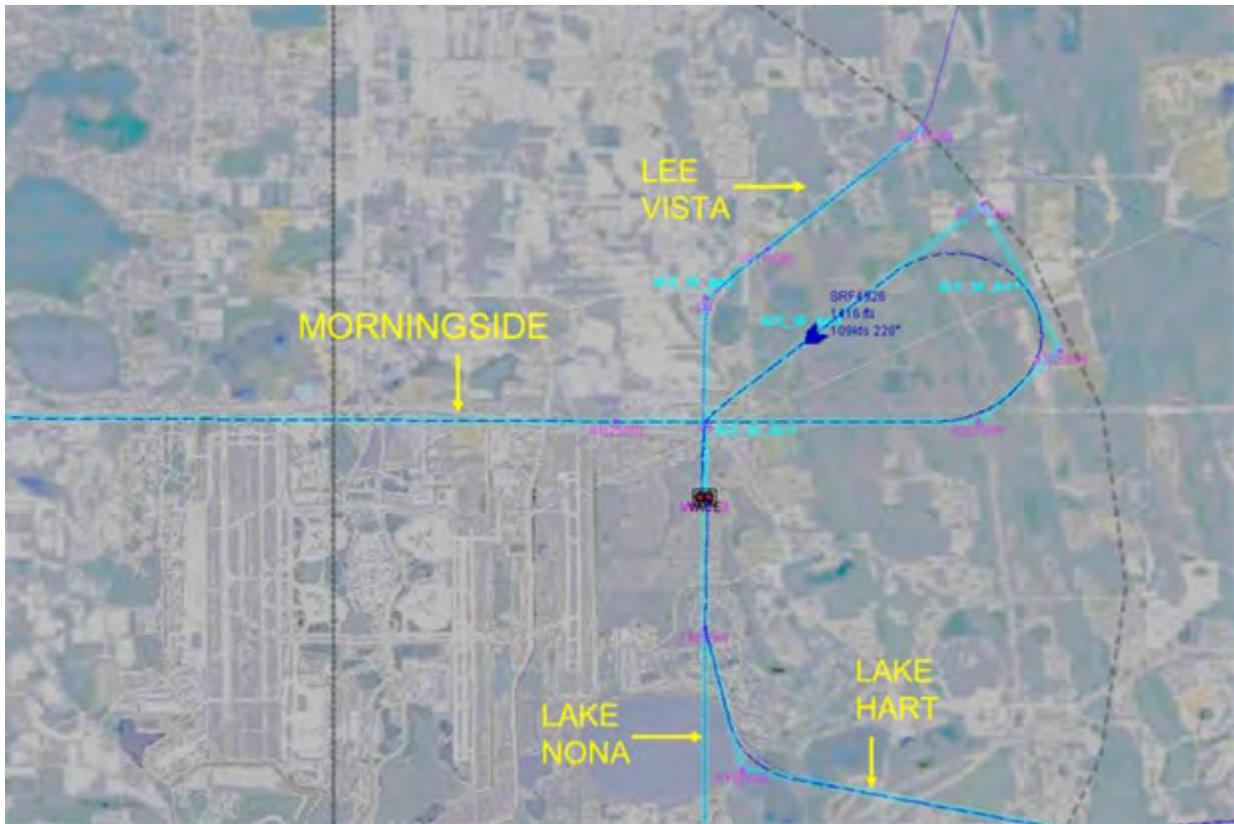


Figure 19. Modified MORNINGSIDE eVTOL arrival route to VACE in south flow configuration

The ATCSs and eVTOL pilots reported that the eVTOL routes worked well overall during this run. The NASA eVTOL pilots reported that the last 45-degree turn onto final approach for VACE could be challenging for an inexperienced pilot due to the complexity of the maneuver. The eVTOL pilots also noted there were eVTOL aircraft on routes at the same altitude and travelling in opposite directions. However, the ATCSs said that this type of conflict would be resolved by the TRACON before being handed off to the ATCT.

The FAA eVTOL pilot did not report any issues during this run and performed unplanned contingency maneuvers at the direction of ATC. The FAA eVTOL pilot initially landed at VACE and was then instructed by the Class B ATCS to reposition to VMMH. After landing at VACE, the FAA eVTOL pilot departed VACE on the LAKE HART eVTOL departure route and joined the SEMORAN EAST eVTOL arrival route to land at VMMH. The Class B ATCS instructed the FAA eVTOL pilot to “go around” during the first approach to VMMH. The Class B ATCS treated the go around like an eVTOL aircraft departure and instructed the FAA eVTOL pilot to circle back to VMMH and maintain 500’ MSL. The ATCSs said that they would normally have a published missed approach procedure that would make the go around more

predictable and create procedural separation. The ATCSs also stated that they would prefer to have an alternate landing area that they could use in case of emergency and as an alternative to directing an eVTOL to complete a full go-around procedure. As the FAA eVTOL pilot was completing the go-around procedure and preparing to land at VMMH, the Class B ATCS instructed him to land on RWY 17L instead. The FAA eVTOL pilot performed a vertical landing on the numbers of RWY 17L and then hover taxied to taxiway J, held short of taxiway K at RWY 17R, and continued a hover taxi to the VMMH TLOF. One of the NASA eVTOL pilots reported that they were approaching VMMH to land when other eVTOL aircraft were present and near the TLOF. However, the eVTOL pilots were able to maintain visual separation and execute safe operations at the vertiports by hovering for short durations to ensure they were clear of other eVTOL traffic. The MMAC A330 pilots reported that the eVTOL traffic was relatively “close” but the operations felt safe and there were no serious issues.

The ATCS at the Class B position appeared to have relatively high communication task load during this run. The Class B ATCS performed voice communications at a relatively higher rate than either the LCW or LCW ATCSs. Not only did the Class B ATCS make and receive more radio transmissions than the other ATCS positions, but the transmissions also tended to be longer in duration overall. The voice communication metrics for this run are shown in Table 14.

Table 14. Voice Communication Metrics for Run 11, Scenario 11, VWST, VMMH, and VACE South Flow

<b>Comm Position</b>	<b>Duration (sec)</b>	<b>Number</b>	<b>Average Duration (sec)</b>	<b>Tx/min</b>
<b>Class B</b>	<b>1002.73</b>	<b>287</b>	<b>3.49</b>	<b>6.67</b>
ATCS	624.3	141	4.43	3.28
TGF Pilot	37.13	8	4.64	0.19
eVTOL Flight Sim Pilot	341.3	138	2.47	3.21
<b>Local Control East</b>	<b>791.08</b>	<b>209</b>	<b>3.79</b>	<b>4.85</b>
ATCS	377.3	96	3.93	2.23
TGF Pilot	255.52	81	3.15	1.88
MMAC Flight Sim Pilot	158.26	32	4.95	0.74
<b>Local Control West</b>	<b>540.51</b>	<b>188</b>	<b>2.88</b>	<b>4.37</b>
ATCS	224.76	81	2.77	1.88
TGF Pilot	315.75	107	2.95	2.49
<b>Grand Total</b>	<b>2334.32</b>	<b>684</b>	<b>3.41</b>	<b>15.89</b>

### **4.3 Wake Turbulence**

The research team analyzed the aircraft tracks from each run and applied the wake separation criteria as defined in FAA Order JO 7110.65BB (FAA, 2025). The research team used the TGF data reduction and analysis tools to identify potential wake separation violation events. ATC SMEs reviewed each event to validate the data and determine if a wake separation violation occurred. Only one event met the criteria to be considered a wake separation violation using the guidance presented to participants. However, after the review, the ATC SMEs determined that the event was not a wake turbulence separation violation under current JO 7110.65BB rules. Therefore, no wake turbulence separation violations occurred during any of the assessment scenario runs under the assumptions that were used for this HITL.

### **4.4 Exit Interview**

The Principal Investigator gathered the participants for an exit interview at the completion of all assessment scenarios. The ATCSs, FAA and NASA eVTOL pilots, ATC SMEs, wake turbulence SMEs, and representatives from the FAA Office of Airports, FAA AAM Integration Office, and NATCA all participated in the exit interview. During the interview, the Principal Investigator and other researchers posed questions about the vertiport locations, multiple vertiport operations, eVTOL routes, safety risks, the Class B ATCS position, workload in the ATCT, communication and coordination, and safety tools.

Researchers began the exit interview by asking the participants about the suitability of the vertiport locations and eVTOL routes that they assessed in the scenarios. Researchers wanted to know what worked at each location and what didn't work when operating a single vertiport and when multiple vertiports were in operation. Researchers also asked the participants to consider their responses in terms of both north and south flow operations. The participants had already discussed each scenario in depth in previous post-scenario interviews, and responses tended to reinforce their previous observations.

The participants discussed the VMMH vertiport location first. The ATCSs said that 10 eVTOL ops/hr. at VMMH was a manageable level of operations and that was appropriate for that vertiport. They reiterated their preference to move the BITHLO eVTOL departure route further north to allow more time for legacy departures to climb above the eVTOL traffic. The ATCSs acknowledged that there would have to be additional coordination with the TRACON and ORL to manage traffic north of MCO.

For eVTOL operations at VMMH during south traffic flow, the ATCSs said that they would treat an eVTOL go-around procedure the same as a southbound eVTOL departure. The ATCSs

suggested that the eVTOL go-around procedure for VMMH would be to instruct the pilot to fly straight ahead “on the rail”, develop a plan, and then act based on the current situation. The participants recognized that a go-around was an unlikely event for an eVTOL aircraft because of its ability to hover for short periods of time and reposition like a helicopter but stated the need for a well-defined procedure and LOAs to manage all contingency operations. The participants also discussed the possibility of placing waypoints or other means of precision navigation between parallel runway complexes to ensure separation between eVTOL and legacy aircraft on final approach.

The ATCSs also discussed the ability of eVTOL aircraft to fly higher approaches during north flow operations to maintain separation from legacy traffic. However, the eVTOL pilots reported that a high approach (descending -12 degrees at 40kts, 1200 ft/min, then maintain 500’ MSL inbound before final approach) was difficult. The participants determined that the high eVTOL approach was not workable during north flow operations but may be easier during south flow operations and a more in-depth wake turbulence study was warranted. The ATCS were also concerned about the perspective of the legacy pilots and whether they would be uneasy about eVTOL aircraft operating in close relative proximity. They suggested that the FAA may need to notify legacy aircraft pilots of eVTOL traffic at VMMH via the Air Traffic Information Service (ATIS) or other means. The ATCSs also said that there was some concern that eVTOL departures flying directly to the north from VMMH may get “trapped” by ORL traffic, or there may be fewer options to manage traffic in some northbound operations especially during contingencies.

Further, eVTOL pilots expressed concern that the routes flown during the event do not comply with current regulations 91.119 and 194.302 which requires that aircraft in cruise (wing born flight mode) must abide by airplane minimum safe altitudes no less 1000’ AGL over congested areas except for purposes of take-off or landing.

Next, the participants discussed the VACE vertiport. The ATCSs agreed that 12 eVTOL ops/hr. was a manageable rate and thought a higher rate might be possible but it would depend on ground operations. The ATCSs suggested moving the location of VACE to the mid-point of RWY 17L so that eVTOL aircraft would be further away from the runway threshold during south flow operations. The ATCS also stated their preference for the modified MORNINGSIDE eVTOL arrival route to VACE that provided a less dramatic, 45-degree approach angle that was also preferred by the eVTOL pilots. Participants representing FAA Airports cautioned that all approach paths must conform to the 135-degree approach cone defined by FAA EB-105 (2024). The controllers also commented again on the distance from the ATCT to VACE. Although there

was a clear line of sight to the vertiport, the distance between the ATCT and VACE was so great that ATCSs were unable to verify eVTOL activity at VACE without a visual aid (e.g., binoculars).

The VWST vertiport did not have as many issues related to location, however there are issues relating to compliance to the Airports engineering brief (EB105A) specifically relating to 8:1 airspace protection as well as potential downwash issues. The ATCSs said that they treated eVTOL operations to VWST the same as they would normally treat helicopter operations to that location. Some coordination was required between the Class B and the LCW positions to manage turboprop aircraft that turned to a 270 heading immediately after departure to ensure separation from eVTOL near VWST. However, the participants reported that there were not any wake turbulence issues from legacy arrivals or departures. The FAA eVTOL pilot reported that there was a light pole on the west ramp that created an obstruction at the VWST TLOF.

After focusing on eVTOL operations at each individual vertiport, researchers asked the participants how the combination of multiple vertiports operating simultaneously affected their ability to manage eVTOL and legacy traffic at MCO. The ATCSs stated that a Class B position would be required for communication and traffic management during eVTOL operations, but especially when the Class B position must manage multiple vertiports. The ATCSs thought that the overall rate of air traffic operations was relatively high when all three vertiports were operating simultaneously but believed they would become accustomed to the new operations and workload would become more manageable as they become more familiar with eVTOL aircraft and the Class B position. The ATCSs also reported that visual scanning out-the-window was difficult when all three vertiports were operating simultaneously because of their locations. The Class B ATCS had to continuously pivot and change his point-of-view in the simulated ATCT cab to maintain a visual scan of the airspace and vertiports. The ATCSs suggested that two Class B positions may be needed during high-tempo operations at multiple vertiports to ensure adequate visual monitoring of all eVTOL aircraft.

After receiving feedback on the individual vertiports and multiple vertiport operations, researchers asked the participants questions that focused on more general air traffic issues. Researchers asked the participants what aspects of eVTOL operations posed the greatest safety risk and what strategies or technologies could mitigate these risks. The ATCSs said that eVTOL aircraft crossing the airspace from the east and landing at VWST and aircraft crossing from the west and landing at VACE was the most difficult part of integrating eVTOL aircraft with legacy traffic. Even though transitioning eVTOL aircraft posed some challenges during the scenarios, the participants agreed that many of the situations they saw in the simulation would be resolved

by the TRACON ATCS and would not be issues. The participants also agreed that there would be some initial mistrust of eVTOL pilot skills and their ability to maintain course, especially when flying in situations like on final approach to VMMH. The participants suggested that ATCSs and legacy aircraft pilots would learn to trust eVTOL pilots over time. They also suggested that additional training for ATCSs would help them gain knowledge of eVTOL operations, routes, and aircraft performance characteristics.

Researchers acknowledged the differences for eVTOL and legacy aircraft operations and asked the participants what specific communication or control challenges arose with eVTOL operations and if there were any training or procedural improvements that could enhance communications. The ATCSs reiterated the necessity of the Class B position and the additional communications and coordination that had to take place with the LCW and LCW positions to integrate eVTOL operations. The ATCSs reported that the Class B position was busier than local control during the assessment scenarios but had workload like a typical ground control position. The ATCSs did not report any specific communication or control challenges with eVTOL operations, and they said they treated eVTOL aircraft like they would treat a helicopter. They said that a lot of clearances would be taken care of in the TRACON and standardized in future procedures.

Finally, researchers asked the ATCSs about safety tools they used including low altitude alerts, conflict alerts, and the potential for ASDE-X alerts. The ATCSs reported that low altitude alerts were suppressed during the assessment scenarios and were not an issue. The ATCSs also reported that conflict alerts were not overwhelming or bothersome and they did not receive any nuisance alerts during the runs. Although the ASDE-X system was not part of the simulation, researchers asked the participants if they anticipated any issues with eVTOL operations affecting the ASDE-X safety logic or a potential for false alerts. The ATCSs did not think that there would be any issues with the ASDE-X safety logic because it would be adapted at the facility to manage eVTOL aircraft and reduce the likelihood of false alerts.

## **5 Summary and Conclusion**

The operational assessment demonstrated the potential for integrating eVTOL operations into the existing air traffic system at MCO, albeit with challenges that require further consideration. The research team identified key findings regarding vertiport operations, eVTOL route optimization, safety, training, workload and coordination.

Managing multiple vertiports simultaneously increased complexity and workload. There was a clear need for a dedicated Class B position in the ATCT to ensure effective communication and traffic management even when only one vertiport was in operation. The integration of eVTOL

operations required increased coordination between ATC positions. Modifications to eVTOL routes, such as implementing teardrop patterns and adjusting arrival paths, were beneficial for reducing potential conflicts with legacy traffic and enhancing operational efficiency. Concerns about wake turbulence, pilot skill trust, and contingency operations highlighted the need for comprehensive training and procedural development. The participants emphasized the importance of clear communication and the need to understand eVTOL performance characteristics. Finally, the adaptation of existing safety tools, such as conflict alerts, would be necessary to accommodate the unique performance characteristics of eVTOL aircraft. Table 15 presents advantages and disadvantages that researchers identified for each vertiport regarding line of sight, location, wake turbulence, contingency operations, eVTOL routes, intrafacility coordination, interfacility coordination, and pilot perspective.

Table 15. Vertiport Assessment Summary

	VWST		VMMH		VACE	
	Pro	Con	Pro	Con	Pro	Con
<b>Line of sight</b>	Direct to vertiport		Direct to vertiport		Direct to vertiport (with trees removed)	Distance from ATCT – Requires visual aid
<b>Location</b>	Proximity to runway enables ops to runway	Ramp obstructions (EB105A non-compliance)			Distance from runways enables higher rate of ops/hr.	
<b>Wake turbulence</b>	Mitigated by routes		No issues with legacy arrivals on outboard runways	Requires precise nav	Mitigated by distance from runways	Close to RWY 17 departure wake in south flow
<b>Contingency operations</b>		Only one TLOF		Can get trapped in north flow	More options due to space	
<b>eVTOL routes</b>	eVTOL ops like current helicopter ops	Potential conflicts on shared arrival/dep route	Do not transition across airfield	Complex final approach may be difficult		
<b>Intrafacility coordination</b>		Increased for eVTOL arrivals/dep artures				Increased especially for arr/dep eVTOLs

		crossing airspace				crossing airspace
<b>Interfacility coordination</b>				North flow - Increased with ORL		
<b>Pilot perspective</b>		eVTOL arrivals/dep artures to/from west on same route near vertiport		ATCS concerned that pilots may have issues with proximal eVTOL traffic		

Overall, the assessment underscored the necessity for continued evaluation, modeling, and procedural development to ensure the safe and efficient integration of eVTOL aircraft into the NAS, supporting informed policy and airport development decisions.

## References

FAA (2024). Engineering Brief No. 105A, Vertiport Design, Supplemental Guidance to Advisory Circular 150/5390-2D, Heliport Design.

FAA (2025). Order JO 7110.65BB - Air Traffic Control.