SKYGRID | A Boeing Company.

Concept of Operations for Data Services and ATM Automation

Supporting the Airspace Integration of Advanced Air Mobility

Summary for Air Navigation Service Providers

Foreword

“The desire to fly is an idea handed down to us by our ancestors who, in their grueling travels across trackless lands in prehistoric times, looked enviously on the birds soaring freely through space, at full speed, above all obstacles, on the infinite highway of the air.”

- Orville Wright

Contemporary humans gridlocked on terrestrial highways must also look enviously on the birds soaring freely through space. There must be a better way.

More than a century ago, the persevering genius of Orville and Wilbur Wright ushered forth the history of practical flight. Today, the convergence of autonomy, digitization, and electrification promises to fully open the third dimension of mobility – to render into life, with even greater vividness and fluidity, Orville's infinite highway of the air.

Delivery drones, autonomous cargo aircraft, and air taxis are among the new "advanced aerial mobility" vehicles that will soon soar above and connect our communities. These aircraft upend aviation’s once immutable scaling and economic laws – no longer are vehicles necessarily sized by the pilot.

They challenge the steep performance tradeoffs in vertical and transitional flight with electrification and new configurations. And they usher forth, we hope and engineer, an era of pervasive and accessible aerial mobility.

SkyGrid answers this call. We exist to open the sky for autonomous aviation and advanced air mobility. We achieve this by delivering assured data, decision support, and infrastructure integration to support AAM operations, autonomous aircraft integration, and airspace automation. And we know with conviction that we must do this at a demonstrably high level of assurance.

This Concept of Operations (ConOps) sets forth our vision for integrating AAM and autonomous aviation into today's airspace. The capabilities outlined in this ConOps will operate even more efficiently and support more aviation segments as the global airspace digitizes. We write this ConOps to help elevate and enrich the vital conversation around AAM operations and airspace integration. Your feedback and engagement will help us make this vision real with OEMs, operators, regulators, and our partners at Boeing and Wisk. On a mission that takes a literal global village, we must not – and will not journey alone.

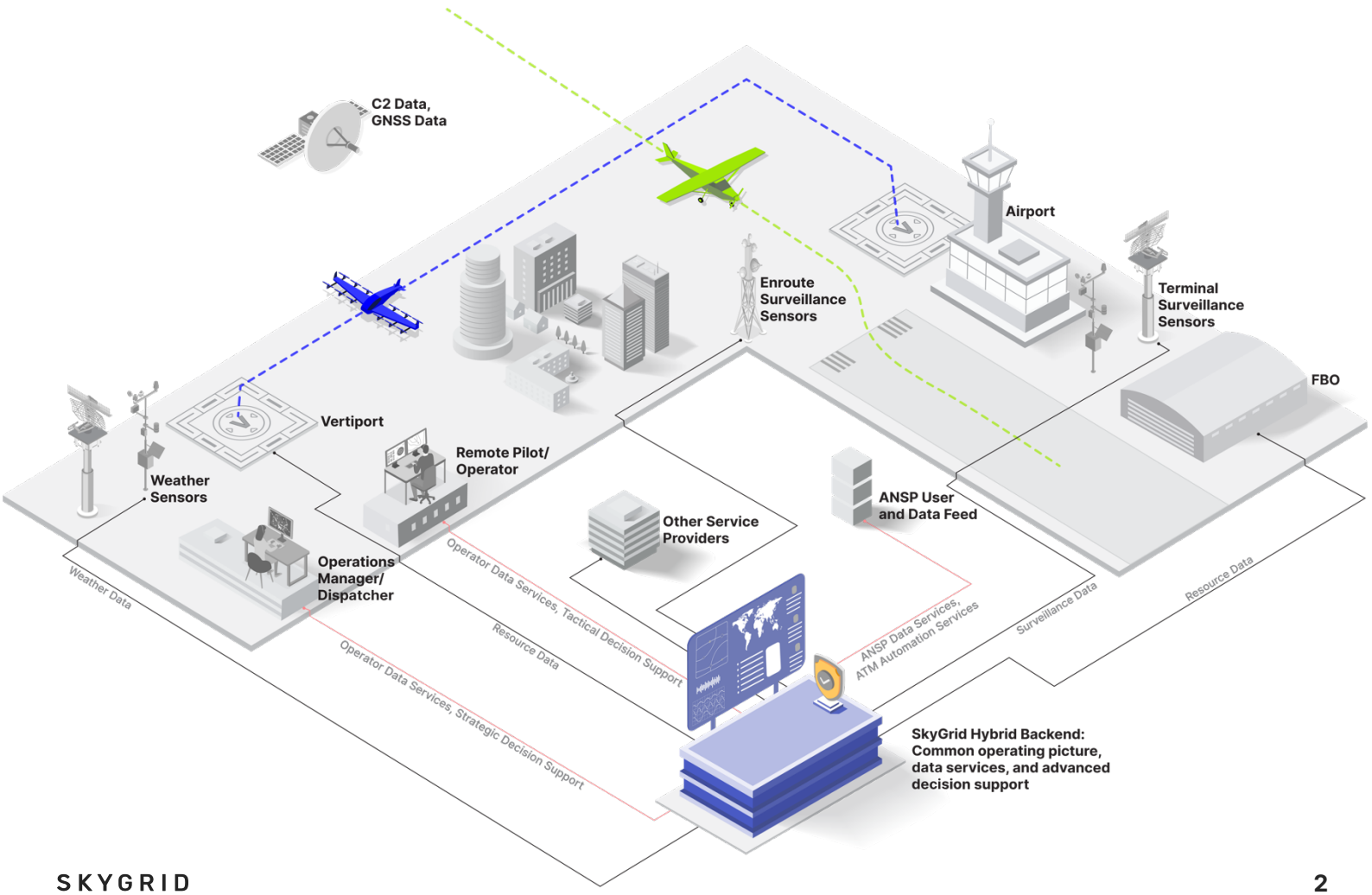
Jia Xu
CEO, SkyGrid

Introduction

Advanced Air Mobility, or AAM, promises to introduce several novel operations into the global airspace system over the next decade, with example missions including vertical take-off and landing (VTOL) operations in urban environments and remotely operated fixed-wing operations in regional settings. While the proposed use cases for AAM are diverse, they generally share the use of highly automated aircraft, ranging from Simplified Vehicle Operations (SVO) with a pilot on board to uncrewed operations with a remote supervisor.

Given an industry focus on urban and regional markets, AAM operations will often take place in highly complex, structured, and constrained airspaces. These environments will impose several requirements on AAM operations, including the need to not disrupt existing aircraft operations and to not disproportionally increase the workload of air traffic controllers. In addition, uncrewed AAM operations will require new real-time data to safely operate alongside traditional piloted aircraft.

To operate effectively in this context, AAM operations will require new data services and Air Traffic Management (ATM) automation. SkyGrid, a Boeing company, is developing a ground-based system to help Air Navigation Service Providers (ANSP) address these emerging needs.



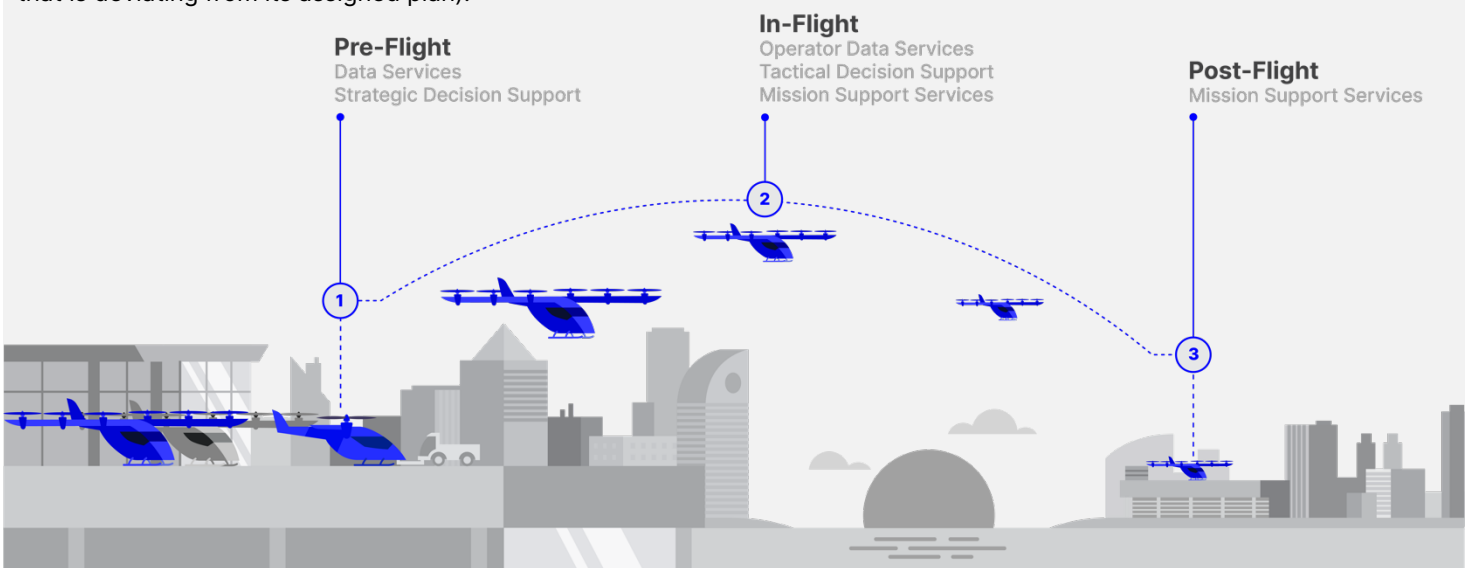
The foundation of SkyGrid's system is a **high-fidelity** and **high-assurance** digital representation of the airspace. This "digital twin" of the airspace will be shared with AAM operations, either by the local ANSP or SkyGrid (on behalf of the ANSP), providing them with accurate real-time and forecast information from their operating environment, including information on traffic, weather, airspace structure, and ground infrastructure.

Leveraging this digital twin, SkyGrid is also developing ATM automation in the form of strategic and tactical decision support services. These services may be provided either to an AAM operator to the ANSP and will contribute to the airspace integration of AAM missions. For instance, the SkyGrid system will be able to process flight plans submitted by AAM operators and verify that they are safely deconflicted from other operations and airspace constraints communicated by the ANSP. Through another decision support service, the SkyGrid system will be able to generate traffic flow advisories to either the ANSP or to operators to help meter AAM departures according to traffic flow constraints (e.g., airport/vertiport acceptance rates) and aircraft separation rules.

This ConOps provides an overview of the SkyGrid system, its envisioned use, and planned capabilities during early to midterm AAM operations. During this period, SkyGrid expects that AAM operations will take place using Visual and Instrument Flight Rules (VFR and IFR) without changes to airspace structure, and with ATC retaining responsibility for providing air traffic services. This ConOps also describes SkyGrid's vision for how the role of its system may evolve as ground-based capabilities, AAM operations, and operational rules mature. This ConOps is intended for all stakeholders who will use, support, regulate, or otherwise interact with AAM operations.

Operational Vignette

AAM operators may receive data services from the SkyGrid system, ensuring they have a detailed operating picture from which flights can be planned and executed safely, efficiently, and with high predictability. Additionally, SkyGrid will provide strategic and tactical decision support services to the local ANSP to directly enable the integration of AAM missions into the airspace. For pre-flight tasks, the SkyGrid system will be capable of validating flight plans to ensure they are deconflicted from other flights and to verify the availability of ground resources. Supporting in-flight tasks, the SkyGrid system will be capable of identifying and highlighting potential conflicts, weather hazards, and non-conformance conditions (e.g., an aircraft that is deviating from its assigned plan).



Roadmap for SkyGrid's Data Services and ATM Automation

SkyGrid is taking an evolutionary approach to system development, with the intent of eventually offering high-assurance automation to support the traffic management of mature AAM operations. In this future state of operations, the SkyGrid system will be capable of supporting the cooperative management of AAM operations with a high degree of automation, contributing directly to the scaling of operations.

Based on this long-term target, SkyGrid has identified three phases of operation for its system, with earlier phases supporting the integration of AAM operations within the current air traffic system and under existing regulations. As the SkyGrid system matures, specific services provided by SkyGrid will evolve from being informational-only, to providing alerts and advisories, to providing automated decision-making and being delegated responsibility for safety-critical tasks. The three phases of system operation, along with their anticipated timelines, are described below.

Phase I
(Entry-into-service, 2026-2028)

The SkyGrid system will initially support ANSPs in providing a digital twin of the airspace to AAM operators. This information will be provided by SkyGrid's Data Services and will offer operators a detailed understanding of their operating environment. During this phase of operations, the SkyGrid system will support operators with pre-flight tasks such as flight planning, offering a higher degree of mission predictability. During this phase, the SkyGrid system may also be used by operators of uncrewed aircraft as a source of information for in-flight situational awareness and decision-making.

Phase II
(2028-2032)

During this phase, the SkyGrid system will provide additional decision support services to support ANSPs in managing AAM traffic. These services are represented by SkyGrid's Strategic and Tactical Planning Services and will offer alerting and advisory capabilities. The addition of decision support services during this phase of operations will contribute to more efficient AAM flights and reduce the need for ATC intervention in AAM operations, leading to more scalable operations. SkyGrid anticipates that this phase will offer opportunities for gaining experience with new ATM automation in a decision support capacity while producing evidence to support more advanced automation in the future.

Phase III
(2032+)

In this phase, the SkyGrid system will support mature AAM operations within dedicated AAM routes or corridors, which may be conducted without direct ATC involvement. In the transition to this phase, SkyGrid expects that its system will transition from providing decision support to providing automated decision-making in a responsible capacity, helping to maintain a safe and orderly flow of traffic within AAM corridors. Services offered by SkyGrid in this phase will consist of evolved forms of the decision support services offered in Phase II.

This ConOps focuses on describing the operation of the SkyGrid system during Phase II, during which the system will provide data services and decision support capabilities to support ANSPs with the airspace integration of AAM missions in the current airspace system. A more detailed discussion of Phase III will be the target of future SkyGrid publications.

Principles and Assumptions

The table below summarizes the key assumptions made by SkyGrid on the AAM operating environment during Phase II of its system's operation.

Feature of Operating Environment	Assumption
Flight Rules	Crewed AAM operations will take place using existing VFR and IFR rules. Uncrewed AAM operations will take place under IFR only.
Airspace Structure	Existing airspace and sector structure will be retained. Airspace "keyholes" or "carve outs" may be used to omit the airspace above vertiport locations from controlled airspaces.
Air Traffic Services	Aircraft separation and traffic flow management will be provided by Air Traffic Control (ATC) in controlled airspaces. The SkyGrid system may support traffic flow management by producing traffic flow advisories.
Separation Standards	Existing separation standards will be retained. Uncrewed aircraft will satisfy Remain Well Clear requirements using a combination of new airborne and ground-based systems.
Routes	Existing VFR corridors and ATC-preferred IFR routes will be leveraged where applicable. New IFR routes may be created to serve AAM operations. Routes will provide higher predictability of AAM operations.

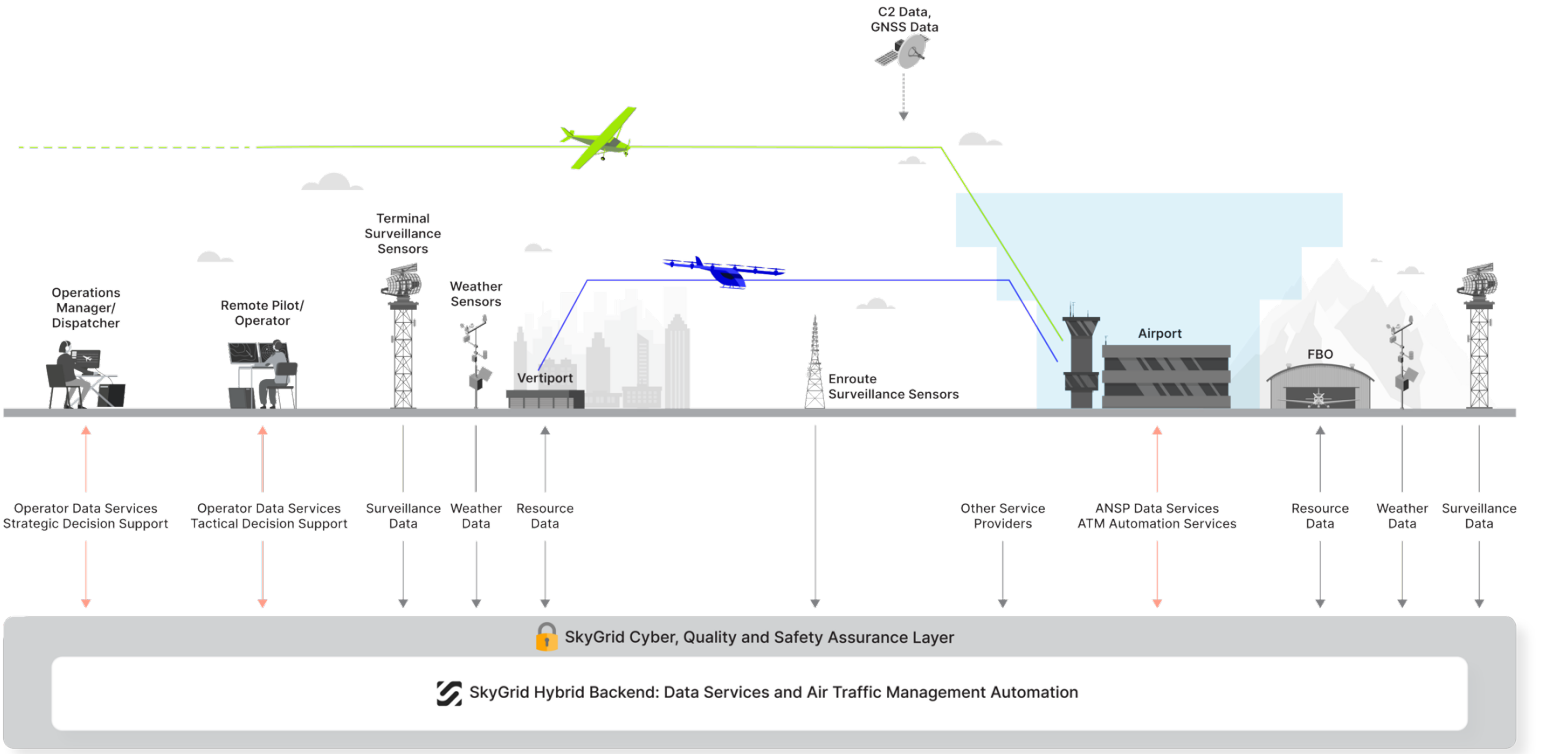
Feature of Operating Environment	Assumption
Instrument Flight Procedures (IFP)	Existing IFPs will be leveraged where applicable. New NavSpecs and IFPs may be created to serve uncrewed AAM aircraft, including approach procedures that support automated landings with no visual segments.
Communication Infrastructure	Existing two-way VHF communication between AAM operators and ATC will be retained. Ground-to-ground communication may be established between a Remote Pilot or Remote Supervisor and ATC. Datalink will be leveraged where applicable, such as for Pre-Departure Clearances (PDC).
Surveillance Infrastructure	Existing surveillance infrastructure will be leveraged (ADS-B, ASR-9, ASDE-X, WAM, etc.). New low-altitude surveillance sensors may be installed in the local areas of airports and vertiports to augment surveillance coverage.
Takeoff and Landing Sites	VTOL aircraft will operate from existing airports and vertiports. New vertiports may be built. CTOL aircraft will operate from existing airports. The SkyGrid system will interface with vertiports and airports to verify the availability of ground resources for AAM aircraft.
Role of the SkyGrid system	The SkyGrid system will provide data and decision support services to support ANSPs in integrating and managing new AAM traffic. These services will improve the predictability of AAM operations and minimize their impact on existing operations.

Overview of SkyGrid System

The SkyGrid system will be a ground-based system with a user interface and API access. The system is being designed based on aviation standards to serve as a high-assurance source of flight information, advisories, and alerts. The system will be capable of delivering various digital services to ANSPs and operators to support the airspace integration of novel AAM operations.

Development of the SkyGrid system is guided by four high-level system goals:

- **System Goal 1:** Provide a high-fidelity and high assurance “digital twin” of the operating environment to enable a common operating picture among AAM operators.
- **System Goal 2:** Enable uncrewed AAM operations by providing high-assurance and low-latency traffic surveillance data needed to satisfy remain-well-clear and collision avoidance requirements without a pilot onboard.
- **System Goal 3:** Increase predictability of operations by providing flight planning solutions based on detailed knowledge of the airspace and resource availability.
- **System Goal 4:** Provide ATM automation to minimize the impact of new AAM operations on existing operations and air traffic controller workload.



A high-level operational concept graphic (OV-1) for the SkyGrid system is shown in the figure below, highlighting the external interfaces of the system.

The SkyGrid system will support the airspace integration of both crewed and uncrewed AAM operations by delivering data and decision support services. SkyGrid data services may be used by Operations Managers/Dispatchers responsible for planning flights and dispatching aircraft, and by Remote Pilots of uncrewed aircraft to monitor their operating environment during a flight. SkyGrid strategic and tactical decision support services may be provided to operators and ANSPs. These services will generate advisories and recommendations regarding AAM flight plans, departure sequencing, and enroute flow management.

The SkyGrid system will receive and aggregate data from multiple sources, including Surveillance Data Providers, Weather Data Providers, Aeronautical Data Providers, and C2 Data Providers. Data will be received, processed and distributed using secure processes. Safety-critical data will have additional requirements for security, latency, and assurance.

Traffic surveillance will be supported by new commercial surveillance sensors deployed by Surveillance Data Providers, as well as dependent surveillance broadcasts from aircraft (i.e., ADS-B). In terminal environments (i.e., in the vicinity of vertiports and airports), Surveillance Data Providers will provide additional low-altitude coverage. Similarly, Weather Data Providers will deploy and operate new sensor infrastructure for assessing weather conditions at new takeoff and landing sites.

Data on the status and capacity of vertiports and parking ramps (e.g., at Fixed-Based Operators, or FBOs) are expected to be shared by the respective facilities for the purpose of AAM flight scheduling. Additional information on the status and capacity of airspace and airport resources may be received from the local ANSP.

Examples of Planned Services

Services to delivered by the SkyGrid system are classified under four types:

Data Services, Strategic Decision Support, Tactical Decision Support, and Mission Support Services. A list of services proposed under each category is shown below, with additional service descriptions available in the full version of this ConOps.

Data Services

- Terrain and Obstacle Data
- Weather Data
- Ground-Based Traffic Surveillance
- NOTAMs
- ATM/TSP Integration
- Aerodrome and Airspace Data
- C2 and GNSS Performance Data
- Resource Status and Capacity Data

Strategic Decision Support

- Advanced Flight Planning
- Flight Plan Validation
- Demand-Capacity Balancing
- Traffic Synchronization
- Operational Area Forecasting

Tactical Decision Support

- Dynamic Rerouting
- Hazard and Constraint Monitoring
- Flow Management
- Conformance Monitoring
- Ground-Based Detect-and-Avoid

Mission Support Services

- Flight Tracking
- Mission Recording
- Operations Data Management

Data Services

SkyGrid's Data Services will provide operators with high-fidelity information about their operating environment, supporting their situational awareness and equipping AAM operators with a common operating picture for collaboration decision-making. Example services in this category include *Ground-Based Traffic Surveillance (GBTS)* and *Resource Status and Capacity Data*.

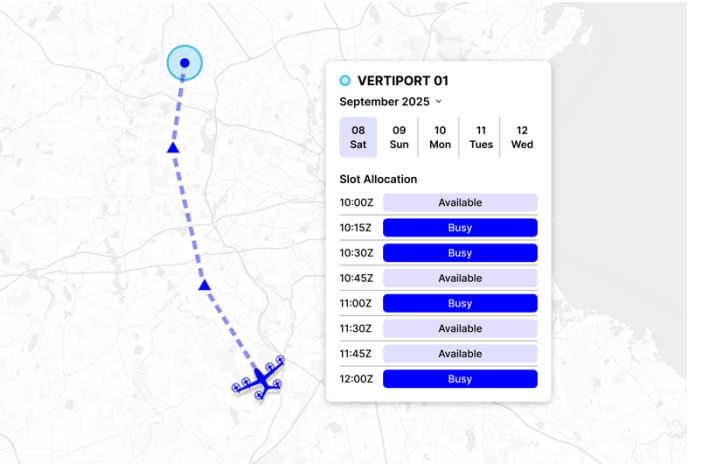
Ground-Based Traffic Surveillance (GBTS)

GBTS will integrate traffic information from several surveillance sources to provide operators with a complete traffic picture of their operating environment. Operators will receive high-integrity and low-latency traffic surveillance data, including tracks for cooperative and non-cooperative aircraft. In addition to aircraft track data, the SkyGrid system will provide real-time data on the performance of surveillance systems and expected coverage volumes. This data may be visualized in real-time by operators via the SkyGrid user interface or received through an API.

Notional User Interface (UI) view of SkyGrid's Ground-Based Traffic Surveillance service, showing traffic in the airspace.

Resource Status and Capacity Data

The Resource Status and Capacity Data service will provide operators with information on capacity-constrained resources, including vertiports, airport runways, and parking stands. This service will allow operators to plan flights based on the known availability of takeoff and landing sites, ensuring that operations remain predictable and well-coordinated. SkyGrid envisions receiving and integrating data from Vertiport and FBO systems as part of this service.



Notional User Interface (UI) view of SkyGrid's Resource Status and Capacity Data service, showing available slots for arrival and handling at a vertiport.

Strategic Decision Support

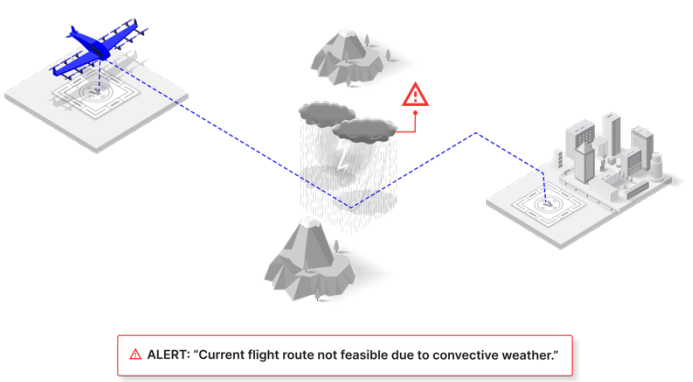
Strategic Decision Support services consist of services that will help users plan AAM flights that are safe, efficient, and predictable – all while satisfying airspace constraints. Example services in this category include *Flight Plan Validation* and *Traffic Synchronization*, which will leverage the highly detailed digital representation of the operating environment that makes up SkyGrid's Data Services.

Flight Plan Validation

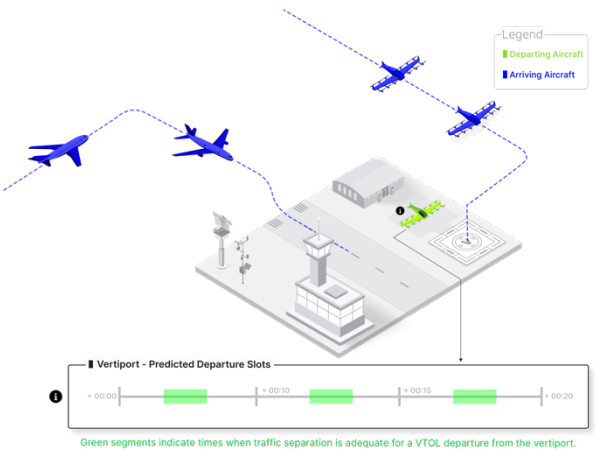
After an operator has prepared a flight plan, the Flight Plan Validation service will begin to perform periodic validations to ensure its feasibility up until departure. The Flight Plan Validation service will monitor hazards and constraints that are considered dynamic (i.e., time-varying) – if a new hazard or constraint is detected that makes the original flight plan infeasible, the operator will be alerted. Hazards and constraints monitored as part of this service will include airspace closures, availability of surveillance services, hazardous weather, resource capacity, and changes in airspace configuration. In the future, this capability may be leveraged by an ANSP to automatically review and approve AAM flight plans.

Traffic Synchronization

The SkyGrid system will be capable of providing air traffic controllers and traffic management coordinators with advisories of feasible takeoff times for upcoming AAM flights, based on real-time traffic conditions and local aircraft separation rules. By highlighting times when an AAM aircraft can safely depart from a vertiport or airport, SkyGrid's Traffic Synchronization service will help controllers identify acceptable departure "gaps" with minimal added workload. In addition, by considering enroute traffic flow constraints in its advisories, the Traffic Synchronization service will reduce the need for further sequencing of AAM aircraft in flight. In the future, this capability may be leveraged by an ANSP to automatically clear AAM departures.



SkyGrid's Flight Plan Validation service will periodically re-evaluate a submitted flight plan and alert the user if the plan becomes infeasible.



SkyGrid's Traffic Synchronization service will advise users of available departure slots for AAM operations based on real-time and scheduled traffic data.

Tactical Decision Support

Tactical Decision Support services consist of services such as *Flow Management* and *Ground-Based Detect-and-Avoid (GBDAA)*, which will support operators and ANSPs in managing new in-flight hazards and constraints that may otherwise affect the safe and orderly flow of AAM traffic.

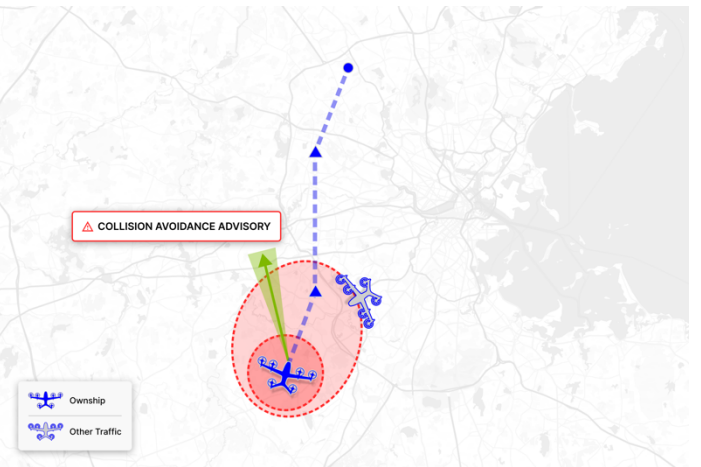
Flow Management

SkyGrid's Flow Management service will assist users in maintaining an orderly flow of traffic on dedicated AAM routes. To achieve this, the Flow Management service will monitor traffic flow on these routes and issue flow management advisories to users when applicable. Traffic flow parameters monitored by the SkyGrid system will include: 1) in-trail spacing between aircraft on AAM routes, 2) expected times of arrival of AAM aircraft at waypoints, and 3) expected times of arrival of AAM aircraft at vertiports or airports.

Ground-Based Detect-and-Avoid (GBDAA)

GBDAA will provide users with in-flight alerts and advisory guidance to keep aircraft clear of one another using both cooperative and non-cooperative ground surveillance data. In the event of a loss of well-clear separation between two aircraft, the GBDAA service will also be capable of providing collision avoidance advisories to AAM operators following applicable industry standards. This service will support uncrewed operations towards satisfying the operational requirement to remain well clear of other traffic without a pilot onboard.

Notional user view of SkyGrid's Flow Management service, showing a speed change advisory to maintain in-trail separation between aircraft.



Notional user view of SkyGrid's Ground-Based Detect-and-Avoid service, showing a collision avoidance advisory.

Feedback

We invite your input and feedback on this concept of operations for data services and ATM automation supporting the airspace integration of advanced air mobility.

Please send an email with feedback to conops@skygrid.com.

Disclaimer:
Please do not include any confidential information in your feedback. Feedback becomes the property of SkyGrid, LLC.

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