Vehicle Collaboration Strategy and Common Reference Models

Mark Moore
Director – Uber Elevate Vehicle Systems
Uber Elevate Transformative VTOL Workshop Participation

- Vehicle Collaboration Strategy - Mark Moore (Vehicle Systems Director)

  Friday

- eVTOL Analysis Tools and Framework - Rob McDonald (Vehicle Design/Tools Head)

- Urban Air Mobility (UAM) Airspace - Tom Prevot (Airspace Director)

- UAM Skyport, Cabin, and User Experience - John Badalmenti (Design Head)

- UAM Ground Infrastructure - Stan Swaintek (Operations Head)

- UAM Community Noise – David Josephson (Acoustics Head)
Why Uber?

UAM has a unique opportunity to design the entire transportation system up-front,

Instead of having vehicles show up ad-hoc with mismatched requirements,

Instead of forcing vehicles into existing infrastructure,

Instead of developers needing to believe “if we build it, they will come”

We have come, and we can connect builders to 65 million users

With a light infrastructure that can be quickly put in place

With a system design to create a great end-to-end user experience
What is the Uber Elevate Role?

Closing vehicle capability gaps through requirements, standards, user surveys, tools, and technologies that accelerate our partners

Developing a highly efficient airspace-operations-network that provides seamless multi-modal connectivity to users

To Enable Urban Air Mobility
What is Uber Elevate Doing to Navigate the Wheel and Fast-forward to the Future?

Distributed Electric Propulsion Opens Up a Vast eVTOL Design Space for Urban Air Mobility
Elevate eVTOL Requirements Document

Covers eVTOL Design Topics Spanning
- Developmental Timeline
- eVTOL Testing Plan
- Mission and Performance
- Noise
- Operations
- Payload/Cabin
- Economics
- Safety
- Infrastructure

Additional Requirements Documents in Development
- Battery
- CONOPs
- Airspace/Navigation/Communications
- Autonomy/Avionics

Uber Elevate eVTOL Requirements

eVTOL Requirement Introduction

Uber's objective is to implement an urban aerial ridesharing network for large cities across the world. This Elevate Network will provide access to the over 60 million active users in Uber's network in the same method as current ground ridesharing is made available, through the Uber mobile app. Users may select which transportation option (UberX, UberXL, Premet, UberAir, etc.) provides the desired size, speed, comfort, availability, at different cost thresholds. To serve this market, Uber has defined a preliminary mission and requirement set for the Electric Vertical Takeoff and Landing (eVTOL) aircraft based on their envisioned Elevate Network. The overarching principle guiding this emerging transportation solution is that the required infrastructure will be minimized (in terms of size and cost) to maximize the opportunity to distribute access opportunities as much as possible. High-portal distribution minimizes the ground travel time for this multi-modal transportation solution (i.e., both ground and air segments are required to satisfy a door-to-door trip, with the goal of minimizing ground leg and maximizing air leg). The unique aspect of such a transportation solution is that node-based travel can be achieved, versus all ground travel options, which require path dependency. This capability both eliminates route infrastructure investment, and eliminates route-based traffic bottlenecks.

The high-level eVTOL design guidance related to requirement decomposition is shown below, in a prioritized order of perceived importance. The basis for each of these relates to energy storage, performance, economic, and demand studies, which are being performed by Uber. The derived requirements are expanded in detail in the later Requirements and Basis sections pertaining to each area:

- Vertical Takeoff and Landing with short duration hover, operations only from known Vertiports
- Level of safety 2x better than autos, based on millions of passenger miles traveled (10-7 to -8)
- Community noise on the order of 15 dB quieter than existing light helicopters
- All battery electric energy storage, with modular energy storage system for other markets
- Approximately 25-mile average stage length, 60-mile max range with rapid recharge capability
- Minimum 150 mph cruise speed at 1000 feet AGL attitude
- 3-4 Passenger seats (plus pilot, with capability to limit passenger access to pilot)
- Initially single pilot with commercial helicopter rating with cross-training, eventually automated
- Part 135 VFR day and night operations, becoming near-all-weather capable in future
eVTOL Common Reference Models: Intent

• Uber does not intend to build an aircraft, Instead, we intend to:
  • Provide test models for new analysis tools that allow us to share tools with specific concept model examples that prove out the tool functionality.
  • Prove the impact of new technologies that improve eVTOL capabilities
  • Provide Elevate partners design integration examples for addressing vehicle capability gaps, including close proximity noise, precise crosswind handling, transition control and sizing energy/power integrations.
  • Enable NASA and Academia engagement to encourage research through open models to facilitate improved tools with validation datasets
  • Build an understanding of eVTOL concept approaches, and strengths and weaknesses relating to DEP technology application
  • Support urban aviation’s long term market success by building up the community, including publishing content to validate market feasibility
eVTOL Vehicle Design, Analysis, and Optimization Framework

Spans Multiple Disciplines
- Geometry
- Battery & Energetics
- Aerodynamics
- Mass Properties
- Propulsion
- Aeroacoustics
- Mission & Point Performance
- Aeroelastics, Loads & Dynamics
- Optimization
Cabin Interior Common User Experience

SkyView Cabin Window

Bi-Level Passenger Seating
Technologies: Stacked Co-Rotating Vertical Lift Propeller

- Stacked propellers enable non-planar wing benefits (i.e. increased mass flow and tip vortex displacement)
- Co-rotating propellers enable multi-element flap benefits (i.e. FofM and increased thrust during hover)
- Independent electric motors for each co-rotating propeller enables a compact integration with variable azimuth spacing during rotation

A Reintroduction of “Stacked” Propellers and their Potential Benefits for Electric Vertical Takeoff and Landing Aircraft

Michael D. Patterson, Nikolai S. Zawodny, Paul M. Rothhaar, and Mark D. Moore
NASA Langley Research Center, Hampton, VA, 23681

Joint Research Publications are in Development with NASA to Validate this Technology

Prior Art Includes Hamilton Standard Variable Camber Propeller, as well as rotor tests (MAR and others)

Independent hub motors, digitally synced

Reduced Noise and Increased Figure of Merit Hover Benefits
Technology: Stacked Co-Rotating Vertical Lift Propeller-Controller

Spectral Characteristics of Conventional and Stacked Propellers
At Constant Thrust,
Showing Change in Blade Harmonic and Broadband Magnitude

Launchpoint Master-Slave Electric Motor-Controller-Propeller
Precise Azimuth Control and Blade Positioning
(even with disturbance forces over wide rpm range)
Technology: Fuselage-Tailboom / Vertical Lift-Battery Nacelle Flow Control

**Cruise Mode**
Stacked propellers are stowed in tail boom and wing nacelles to minimize drag in cruise flight.

**VTOL Mode**
Deployed propellers blow air past the aerodynamically shaped boom and nacelles to produce side force. Lower flap surface rotates to angle flow and produce a sideslip or yawing moment.
eVTOL CRM OpenVSP Models: Diverse eVTOL Approaches

- eVTOL Common Reference Model 001
  “Wingtip Tilt Propeller + Lift Plus Cruise”

- eVTOL Common Reference Model 002
  “Pure Lift Plus Cruise”