2021 VEHICLE TECHNOLOGIES ANNUAL MERIT REVIEW

ENERGY IMPACTS OF ELECTRIFIED PASSENGER AIR TRANSPORT

Project ID: VAN040

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Overview

Timeline

- Project start: April 2020
- Project end: July 2021
- Percent complete: 80%

Budget

- FY20 Funding: $150,000
- FY21 Funding: $0

Partners

- Argonne National Laboratory (lead)
- GeorgiaTech (partner)

Barriers Addressed

- Aviation is energy-intensive and currently relies almost exclusively on fossil fuels
- Limited low-carbon pathways
- Battery specific energy presently too low for fully electric commercial aviation

Relevance

Commercial Aviation Is a Major source of GHGs

915
MT CO_2

12%
OF CO_2 EMISSIONS FROM TRANSPORTATION

2%
OF ALL MAN-MADE CO_2 EMISSIONS

x2
GROWTH IN TRAFFIC 2019-2038
(PRE-COVID FORECAST)

Urban Air Mobility (UAM): Emerging Travel Mode Enabled by Electrification

- Premium TNC-like service, but affordable enough to impact urban mobility
- Small aircrafts (<10 passengers), w/ Vertical Take-Off and Landing (VTOL) capability
- “Vertiports” throughout the city.

Objective: Evaluate Energy Impacts

- Share of domestic flying that can be switched to electric
- UAM impacts on urban travel
- Technology barriers and enablers (e.g. battery specific energy)
- Overall energy impacts

Approach

Technology Assumptions

- Timelines: 2030, 2040, 2050
- Batteries (specific energy, C-rate, usable energy, etc.)
- Aerodynamics
- Motors and power electronics

Missions

- Cruise Speed
- Rate of Climb
- Mission Standardization
- FAA Reserve Regulations

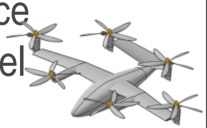
Aircraft Models

Conv./Fixed-wing Aircraft

- Static models
- Mass fractions from existing aircrafts

UAM/VTOL Aircraft

- Tilt-rotor, 4-passenger
- 3D design tool used to establish aerodynamic performance
- Static model



Air Travel Demand

- 2019, domestic
- Source: DOT BTS T-100

UAM Demand Model

- Utility-based mode choice model
- Atlanta and Chicago
- Using Census (LODES), POLARIS data

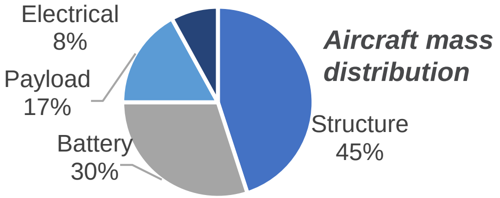
Baseline

- Jet-fuel powered planes

+ → **Electric Energy** → **Fuel saved**

Accomplishments

Developed Fixed-Wing Aircraft Energy Model for Intercity Travel

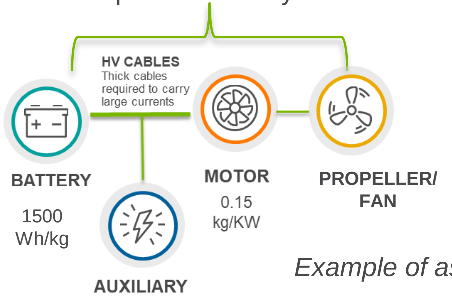


Performance/Design Assumptions

+

Technology Assumptions

Powerplant Efficiency = 95%

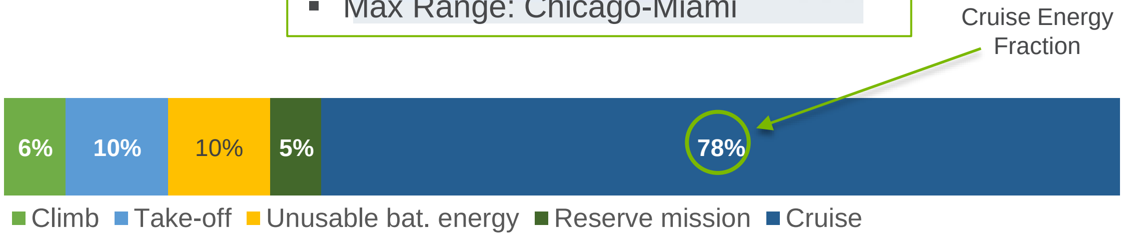


Example of assumptions ~2050

Total Energy + Payload

Standard Mission Profile

2050 Timeline
- 176 passengers @ 90 kg/passenger
- 1200 mi
- Like A320-200
- Max Range: Chicago-Miami

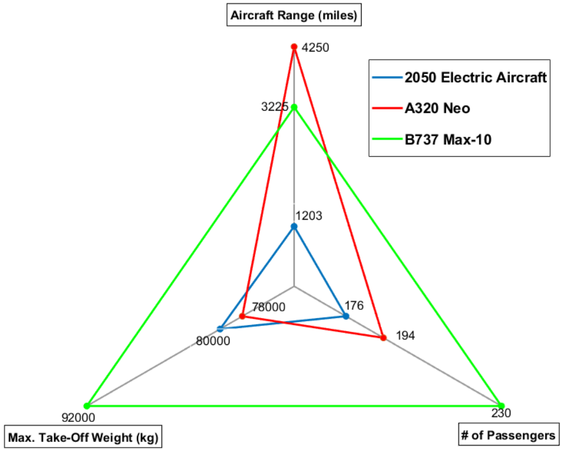


Battery Energy Breakdown

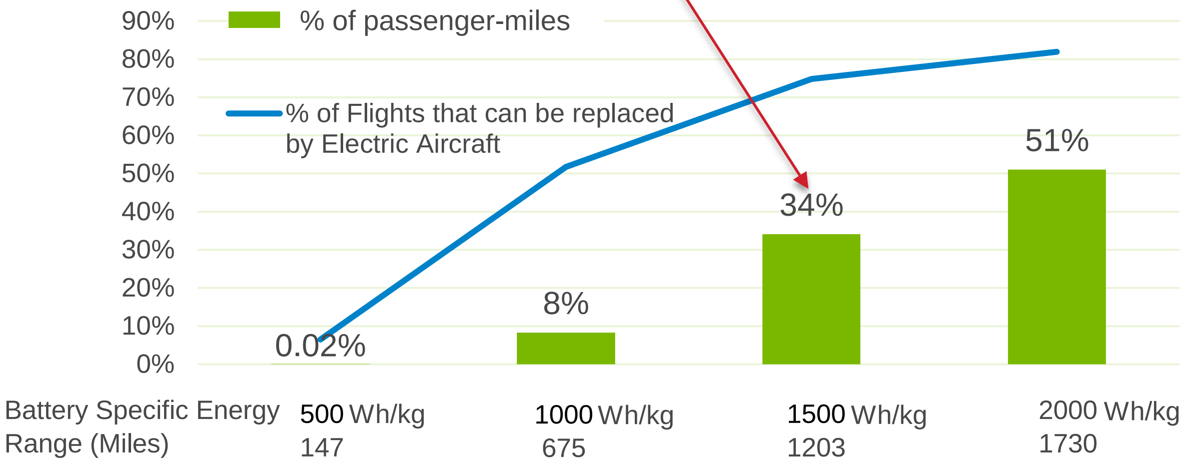
Accomplishments

Combined with Air Travel Data, Model Allows to Estimate Share of Air Travel that Could be Done by All-Electric Planes

Current state of the art vs all electric aircraft (Batt. Dens = 1500 Wh/kg)



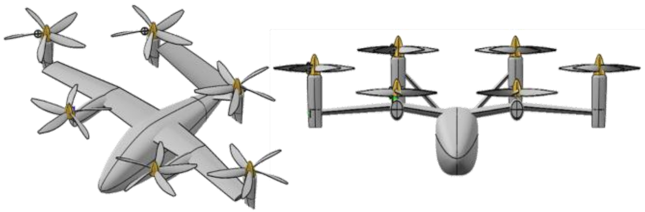
With a 1500 Wh/kg battery (2050), 1/3 of all passenger-miles could be done in all electric



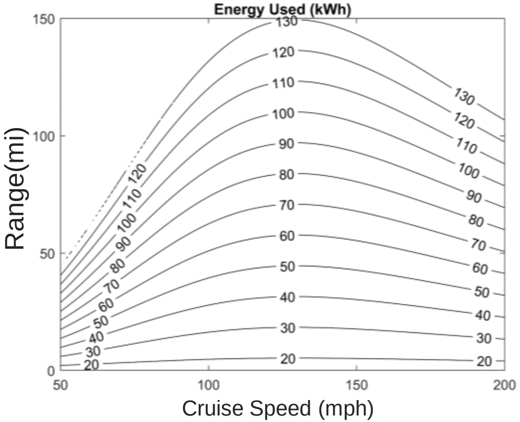
Accomplishments

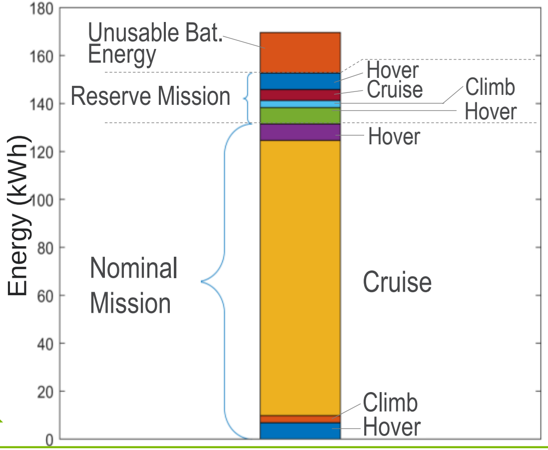
Developed VTOL Aircraft Energy Model for UAM

OpenVSP model of a UAM VTOL Aircraft



- Using available literature to model the shape of a UAM vehicle.
- Drag is estimated using OpenVSP.

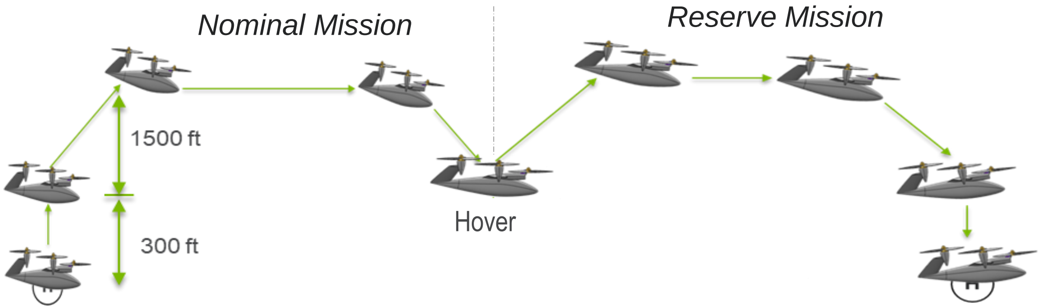




Powerplant Assumptions

- Battery Specific Energy = 235 Wh/kg
- Powertrain Efficiency = 94%
- Propeller Efficiency = 92%
- Battery Reserve = 10%

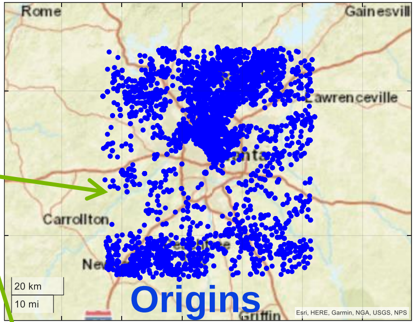
Uber-Elevate Standard Mission



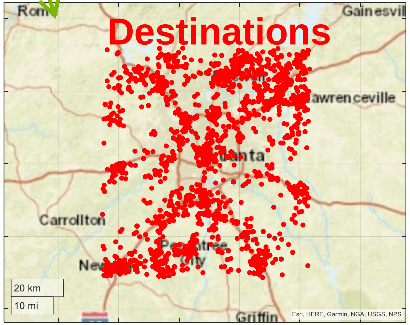
Accomplishments

Developed UAM Demand Model – e.g. Atlanta

High value routes in a city are identified through analysis of travel patterns, income distribution, and travel time

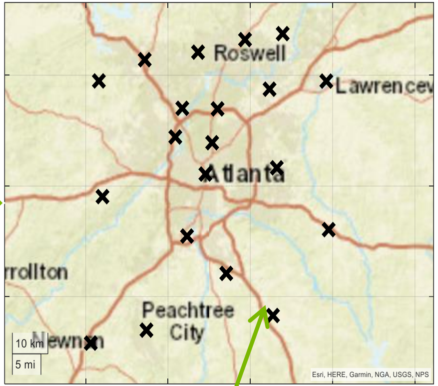


O/D locations for high value routes (n=10,000)



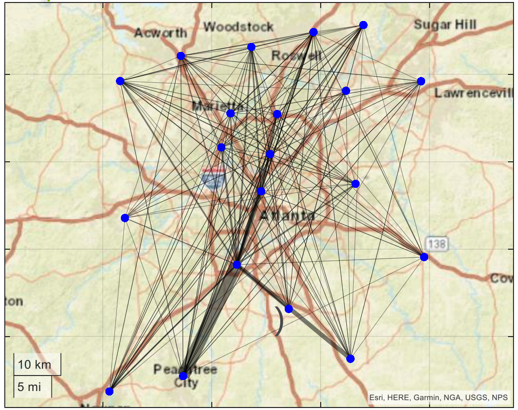
Data sources:

- U.S. Census LEHD Origin-Destination Employment Statistics (LODES)
- American Community Survey (ACS)
- Open Street Maps Routing Machine (OSRM)



The origins and destinations of these routes are clustered to find demand hotspots which serve as locations for a vertiport

A utility-based passenger choice model is developed to simulate the expected behavior of rational individuals about their choice of transportation mode, i.e., car vs. UAM aircraft



Expected UAM service demand for:
UAM Cost: $0.98/mi (Elevate Near Term)
Driving cost: $0.64/mi (AAA 2020)

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Collaboration

Center for Urban and Regional Air Mobility

- Technical assumption compilation
- Intercity aviation modeling
- Travel demand expertise and data (EEMS093)
- Battery SMEs

- UAM/VTOL aircraft modeling
- UAM travel demand model
- Aircraft design

Proposed Future Research

- Finalize technical assumptions (with inputs from SMEs) for each timeline (2030, 2040, 2050)
- Complete Chicago UAM demand model
- Run sensitivity studies around key parameters and analyze trends, including aggregate energy consumption
- Compile and tabulate results for report
- Complete final report (Summer 2021)

Any proposed future work is subject to change based on funding levels

Summary

- Developed a new **electric aviation framework** for passenger travel, first one within VTO:
  - For existing **intercity air travel**
  - For an emerging travel mode, **urban air mobility** (UAM)
- Framework includes:
  - Standardized technology assumptions for **multiple time horizons**
  - Aircraft **sizing** and **energy** models
  - Air travel **demand** models
- A 1500 Wh/kg battery would enable 1/3 of intercity passenger-miles to be flown in all electric aircrafts
- More effort is required for UAMs, an emerging technology for which little data is available:
  - Created a **3D model** of a UAM/VTOL aircraft in a specialized aircraft design tool (OpenVSP) to characterize its performance
  - Developed a **mode choice** model to estimate UAM demand
- All assumptions, model descriptions and analysis will be compiled in a **detailed report** (Summer 2021)