



Reconfigurable Aircraft for Transformational Inter-city Transportation

Kevin R. Antcliff
Aeronautics Systems Analysis Branch, Aero Concepts Incubator



Langley Research Center
Hampton, Virginia

Picture: <https://www.usgs.gov/media/images/goldak-airborne-survey-plane>

Challenge

How can point-to-point, inter-city transportation of people and goods on small, CTOL aircraft become economically feasible?

- Increase utilization
- Lower direct operating costs (pilots, fuel, maintenance, etc.)
- Lower fixed costs (airframe, insurance, etc.)



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<https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-099-DFRC.html>

What's the aircraft name?

Airplane design or concept is expected. This is an on-going effort. Opportunities, requirements, technologies, enablers.

Restate as goal or challenge or study question.

Approach

- Reconfigurable payload
 - Rapidly switched between passenger and cargo configurations
- Airborne electric propulsion
 - Increased efficiency
 - Lower maintenance cost
- Integration of selective autonomy/optionally piloted operations
 - Lowest-risk mission: rural, cargo



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[Image1: https://www.atf.gov/file/peoplejpg](https://www.atf.gov/file/peoplejpg)

[Image2: https://blogs.cdc.gov/publichealthmatters/2017/12/suspicious-package/](https://blogs.cdc.gov/publichealthmatters/2017/12/suspicious-package/)

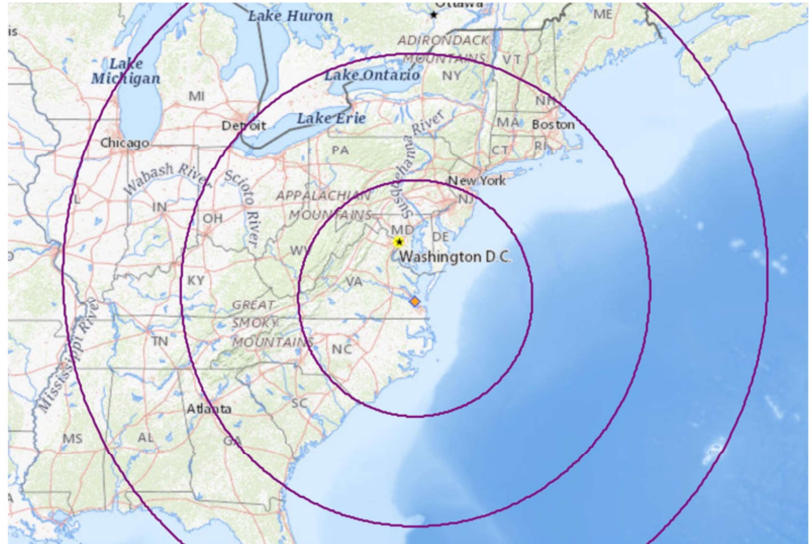
What's the aircraft name?

Picture swap.

Scenario

How far would you drive?

- 250 miles
 - NASA Langley to NYC
 - Car: 6 hours
 - 240 kts: 1 hour
- 500 miles
 - NASA Langley to Louisville, KY
 - Car: 10 hours
 - 240 kts: 2 hours
- 750 miles
 - NASA Langley to Mobile, AL
 - Car: 14 hours
 - 240 kts: 3 hours



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<https://viewer.nationalmap.gov/advanced-viewer/>

Emphasize

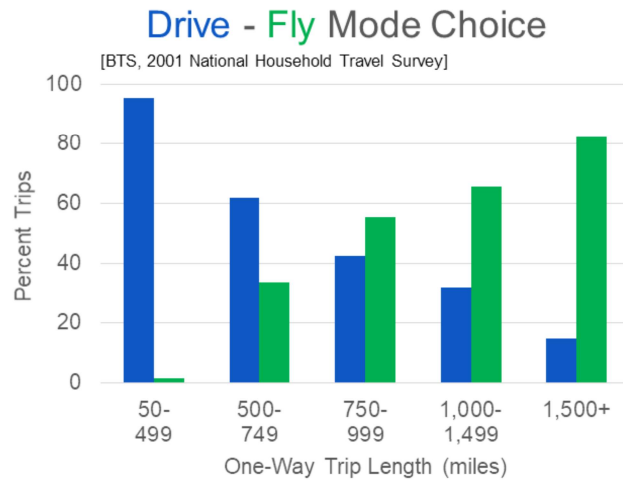
Not just distance, think about access. Major airports are terrible. They just want to go to an airport to go somewhere. Geographic constraints. Cape Air success.

Traffic, flights. State conditions that limit the driving. Anything other than nominal times.

“Regional travel is highly inefficient. It takes almost as long to drive from Alexandria, Virginia, to Atlantic City, New Jersey, as it does to fly from Washington Dulles International Airport to Dublin, Ireland.” –Ben Hamilton, CEO ImagineAir

Motivation

- Cars operate 12x more trips of 50+ miles and > 500x more vehicle miles than air travel



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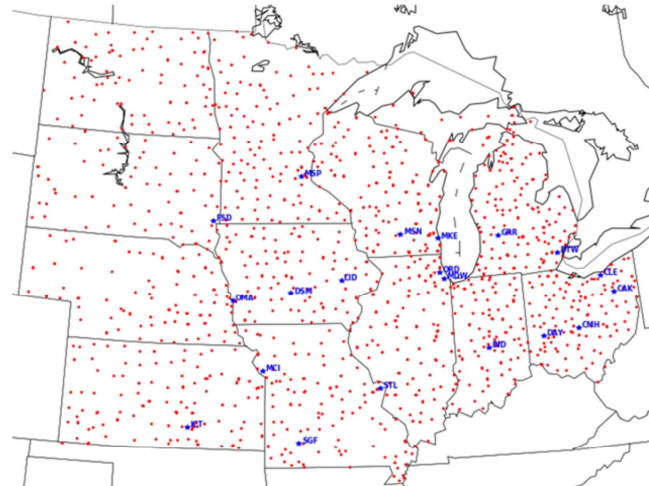
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Huge opportunity. How many trips aren't being taken? Latent demand.

Motivation

- Cars operate 12x more trips of 50+ miles and > 500x more vehicle miles than air travel
- ~30 (0.6%) of the 5,000+ public use airports are major commercial hubs (only 500 w/ any commercial service)



Roy, S. et al., "A Study on the Impact of Aircraft Technology on the Future of Regional Transportation Using Small Aircraft," AIAA Aviation 2018

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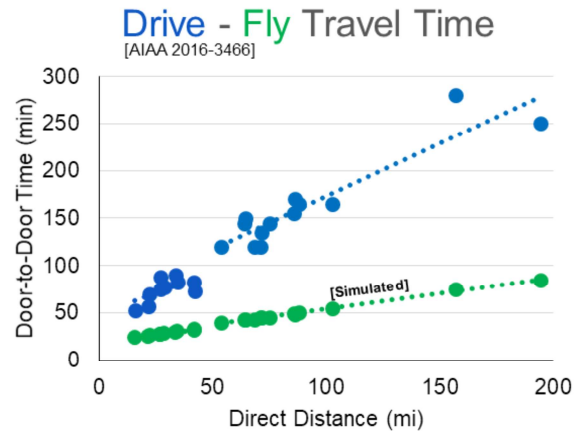
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<https://www.world-airport-codes.com/us-top-40-airports.html>

Public use airports. Over 10,000 private airports.

Motivation

- Cars operate 12x more trips of 50+ miles and > 500x more vehicle miles than air travel
- 500 (10%) of the 5,000+ public use airports are used for commercial passenger operations (~30 major hubs)
- ~2-3x faster than cars & hub-spoke over ~20-500 mile range



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Mandated certain percentage go to regional airports.

Note 2-3 times on average. Early adoption could be on the outliers- not on the averages.

Motivation

- Cars operate 12x more trips of 50+ miles and > 500x more vehicle miles than air travel
- 500 (10%) of the 5,000+ public use airports are used for commercial passenger operations (~30 major hubs)
- ~2-3x faster than cars & hub-spoke over ~20-500 mile range
- Proliferation of e-commerce



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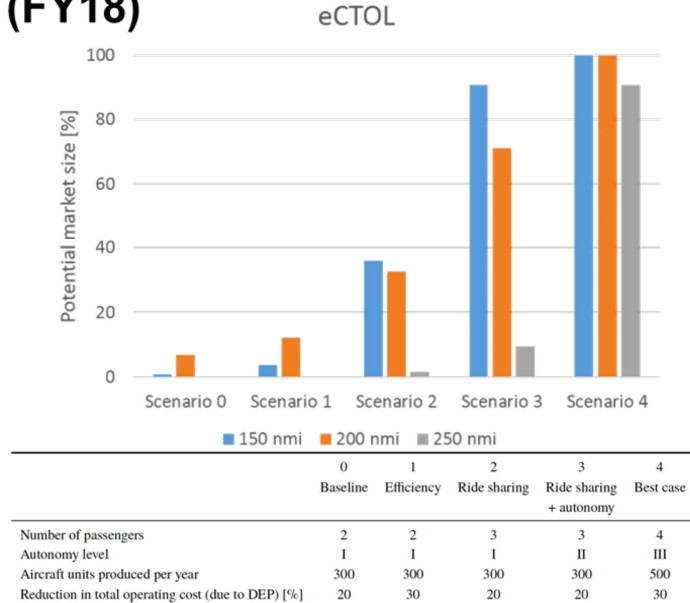
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https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf

Motivation: Purdue Study (FY18)

- Distributed Electric Propulsion (DEP)
 - 7.2% - 12.2% market size
- Ride-sharing
 - 32% market size
- Remotely piloted
 - 39% market size

Roy, S. et al., "A Study on the Impact of Aircraft Technology on the Future of Regional Transportation Using Small Aircraft," AIAA Aviation 2018



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Ground side of cost. How far are we from doing this? What is keeping us from doing this now?

Cape Air exists and make money. Providence Town to Boston. Nantucket, Martha's Vineyard. Essential Air Service. Larger aircraft, low load factor. Fleet is operating. People want to fly on based on higher wing loading.

Explain market size (cost and time value). Recreate Table.

Initial Design Requirements (ARMD Design Challenge)

- 14 CFR Part 135
 - Single pilot
 - 9 passengers or 7,500 lbs
- Entry date: 2025
- 60-min swap
- 99-min max. flight time
- **P:** 120 nmi 9 pax 12-hour/ day 45-minute turnaround
- **C:** 120 nmi 2,000 lb 6-hour/ day 30-minute turnaround

	Threshold	Goal
Max range	200 nmi	500 nmi
Reserves	50nmi + 45min	100nmi + 45min
Field length	1,000', 35' obs.	250', 35' obs.
Noise	80 dB(A)	65 dB(A)

Minimize total cost per seat mile

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Product that you're showing.

Design requirements released this to ARMD UADC to crowdsource the idea to vet the requirements.

ARMD University Aeronautics Design Challenge

NASA

- UC Davis
- Virginia Tech
- University of Virginia

DLR

- University of Stuttgart
- RWTH Aachen University
- Dresden University of Technology



11/20/2019

FY19 CIF/IRAD Final Reviews



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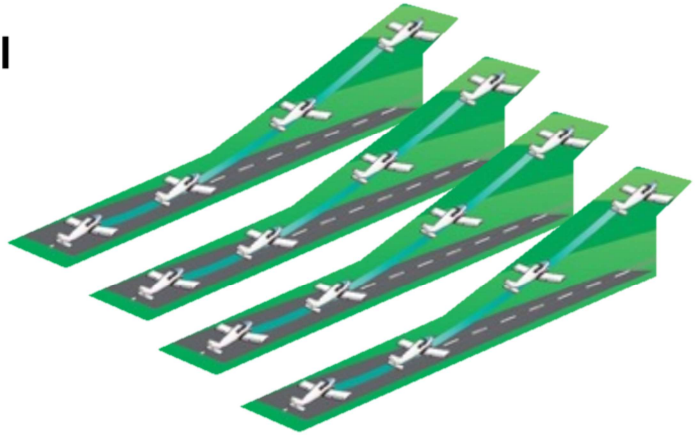
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Photos: <https://www.nasa.gov/aeroresearch/resources/aeronautics-student-competitions/2019/>

High Utilization is Essential

- Part 135 operator
 - Commuter/on-demand
 - 4 flight hours/day (maximum)
 - 1,500 hours per aircraft per year
- Part 121 operator
 - Air carriers
 - 10 flight hours/day
 - 4,000+ hours per aircraft per year
- **Our Goal:** Ability to quickly convert between passenger and cargo configurations increases utilization

– P: 120 nmi	9 pax	12 hours/day	45-minute turnaround
– C: 120 nmi	2,000 lb	6 hours/day	30-minute turnaround
– Total:		18 hours/day	



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https://www.faa.gov/gslac/ALC/course_content.aspx?CID=485&SID=795&previous=true

Data: <http://web.mit.edu/airlinedata/www/default.html>

4 hours and 10 hours. Flight hours.
2500-3000 flight hours. Up to double the utilization.

Speed Helps Throughput

- Evaluating the trade-off between speed, design range, and trips per day (utilization)
- Requirements that drive this sensitivity:
 - 99-minute maximum flight time
 - Must return to “home” airport

Speed (kts)	Market Reach (nmi)	120 nmi. Trips/Day
160	264	12
240	396	14
270	446	16

more trips = more revenue

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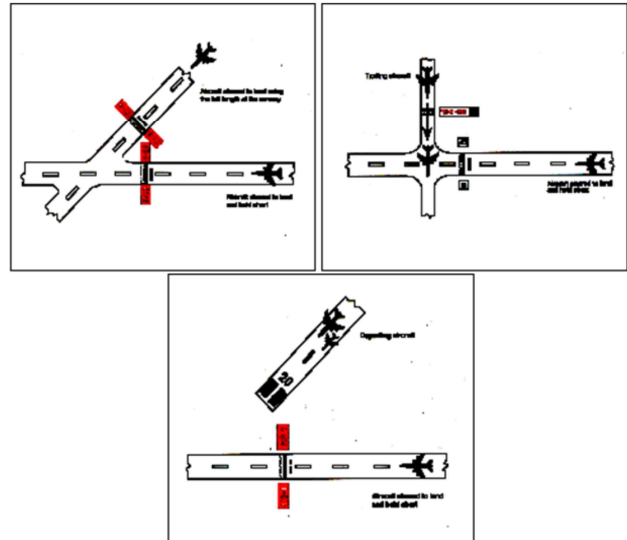
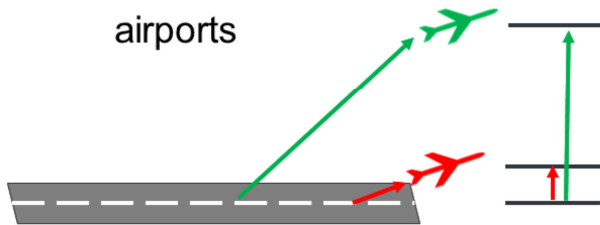


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Market reach.

Short Takeoff and Landing

- STOL gives flexibility for future-proofing of airports
 - Small Airports: STOLports
 - Large Airports: LAHSO (Land and Hold Short Operations)
- Noise reduction outside of airports



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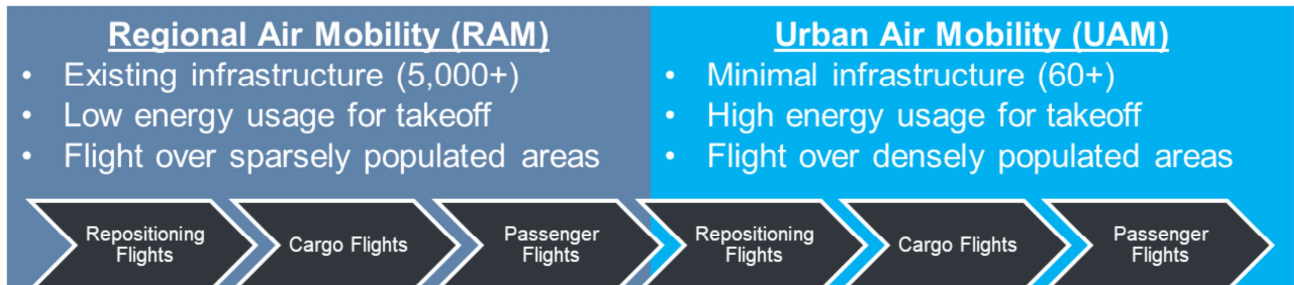
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<http://tfmlearning.faa.gov/Publications/atpubs/AIM/Chap4/aim0403.html>

LAHSO- get these into busy airports through secondary runways that aren't used. Don't effect the capacity. Expands opportunities.

Pathway to Remotely-piloted / Autonomous Operations

- DayJet and ImagineAir ceased operations likely due to their inability to reduce repositioning costs
- We propose a configurable crew station that allows for autonomy to “creep in” over less-populated areas



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<https://patch.com/georgia/gwinnett/10-places-gwinnettians-could-have-flown-to-last-week>

<https://robbreport.com/motors/aviation/new-flight-charters-empty-legs-2883859/>

<https://www.bostonglobe.com/metro/2016/01/22/public-use-heliports-like-one-pondered-boston-are-rare-nationally/wnwxtvevXEE8uPlI8uHJ/story.html>

Less-populated areas. We want to fly over densely populated airports.

Autonomy creep in with no souls on board.

Speel out RAM AND UAM

Conclusions

- There is a large potential market for an electric, shared/pooled, autonomous CTOL aircraft
- Increased utilization helps reduce impact of fixed costs (acquisition, insurance, etc.)
- Increased efficiency and reduced crew costs helps reduce variable costs and can serve as a key enabling pathway toward future autonomous flight
- The reconfigurable concept can be the solution that enables this market

Next Steps

- Refine aircraft and mission requirements, including possible impact of emerging certification standards
- Develop advanced aircraft concepts with varying technology assumptions

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market and operations.



kevin.r.antcliff@nasa.gov

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- The many participants in the ARMD UADC for the exceptional concepts and thorough analyses