Thin-Haul Aviation Operations Study

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Outline

• Introduction to “thin-haul” operations

• Dramatic reductions in operating costs anticipated by Distributed Electric Propulsion (DEP) aircraft concepts

• Focus of our research in DEP-enabled thin-haul operations
**Thin-Haul Commuters** provide Essential Air Services to small communities with ‘thin’ passenger trip distributions. New business models and technologies are developing across many industries to capture ‘long-tail’ markets instead of focusing only on dominant markets. (see *The Long-Tail: Why the Future of Business is Selling Less of More*)

**Example of dominant (green) and long-tail (yellow) market distribution**
(with each being 50% of the total market share)

This is a market valued by the U.S. Congress, which provided $263M in funding to Essential Air Services (EAS) in 2015 to assure aviation access to over 160 remote and underserved communities.
Thin-Haul: Many Business Models

• **Scheduled Operations**
  – Small capacity aircraft
    • < 10 seats
  – Short missions
    • <300 nm
  – Limited ground infrastructure
    • Limited TSA involvement
    • Small terminals / No gates

• **On-Demand Operations**
  – Taxi & charter operators
    • Piston aircraft
    • Multiengine jet aircraft
  – Regional to intercontinental ops.
  – Limited ground infrastructure
    • Usually operate from FBOs
    • No TSA involvement
Thin Haul: Two Successful Operators

Cape Air
- Operations
  - New England ~ 28 routes
  - Midwest & Mountains ~ 13 routes
  - Puerto Rico & US V.I. ~ 18 routes
  - Guam / Rota / Saipan ~ 3 routes
- Aircraft
  - Fleet of 90+ aircraft
  - Mostly Cessna 402 twin-engine piston
- Trip range
  - Max. 220nm / Avg. ~ 80nm

SurfAir
- Operations
  - Predominately California
  - ~ 21 routes
- Aircraft
  - Fleet of 12 aircraft
  - PC-12 single engine turboprop
- Trip range
  - Max. 370nm / Avg. ~ 200nm
Thin-Haul Operating Costs

Fuel is typically one of the largest cost components and its price is very volatile.

Source: BoutiqueAir EAS application, CNM-DFW, 367nm, 1hr08min, PC-12
What Drives Fuel Burn?

C402 with Teledyne Continental TSIO-501-E, 300Hp
Cruise 5,000ft, ISA, 148kt: 2 x 72 lb/hr @ 49.1% BHP
Shaft Power = 0.491*300hp*0.745kW/hp = 109 kW
Power from Fuel = 72lb/hr*5.48kWh/lb = 394 kW
Thermal Efficiency = 109/394= 28%
Specific Range = (148nm/hr) / (144lb/hr) = 1.03 nm/lb
Specific Range = 148 / (144*5.39kWh/lb) = 0.19 nm/kWh

PC-12 with Pratt & Whitney PT6A-67P, 1200Hp
Cruise 20,000ft, ISA, 205kt: 322lb/hr and 19psi @ 1,700rpm
(19psi indication converts to 1614ft.lb)
Shaft Power=1700rpm*1614ft.lb*0.000142kW.min/ft.lb=389kW
Power from Fuel = 322*5.39kWh/lb=1736 kW
Thermal Efficiency = 389/1736= 23%
Specific Range = (205nm/hr) / (322lb/hr) = 0.64 nm/lb
Specific Range = 205nm/hr / (322*5.39) = 0.12 nm/kWh
DEP: A Technology to Revolutionize Thin-Haul Battery Energy Storage

**Specific Range** = 0.71nm/kWh

\[ P_{req.} = \frac{1}{\eta} \cdot \frac{W \cdot V}{(L/D)} \left( \frac{L}{D} \right)_{MAX} = \frac{1}{2} \cdot \sqrt{\frac{\epsilon \cdot \pi \cdot AR}{C_{D,0}}} \]

Dramatic improvements in energy conversion efficiency and higher L/D significantly decreases energy costs
Impacts of DEP on Operating Costs

Baseline: BoutiqueAir EAS application, CNM-DFW, 367nm, 1hr08min, PC-12

Maintenance & Reserves costs?
→ Do long lives of motors decrease needed reserves and routine maintenance?
→ Do short lives of batteries necessitate increased reserves?

Ownership costs?
→ How do we design the operation to maintain aircraft utilization while considering battery charging?

Energy costs?
→ Can optimization of charging strategies further reduce electricity expenses? (peak/day/night rates)

Labor costs?
→ How much can single pilot operations decrease labor costs?
→ Can battery charging strategies be devised to manage turn around times and prevent idling crews at out-stations?

Many possibilities for reducing overall operating expenses by design of DEP aircraft and associated operating paradigms
Reducing Operating Costs Drives Demand

Pricing, demand, and operating costs are strongly coupled:

- Route level elasticity / Short haul ops. / North America: ~ -1.5, e.g. a 10% decrease in price results in an increase in demand by more than 15% (IATA Air Travel Demand – April 2008)
- Thin-haul operations even more elastic due to modal substitution on very short routes

Strong incentive to decrease operating costs in order to lower ticket prices and stimulate demand...
Focus of Our Research

• Model existing thin-haul commuter networks
  – Cape Air, Surf Air, and ImagineAir as case studies

• Model the impact of DEP aircraft concepts developed by Joby Aviation on operations in these thin-haul networks
  – Operations infrastructure & schedule
  – Operator economics (DOC & IOC)
  – Emissions (lowering aviation CO2)
To estimate electrical energy expenses, data such as the following are required:
- Utility provider
- Electricity price schedule
- Peak power
- Energy need

Airports in the Cape Air network are served by many different utility providers
- Eversource
- Niagara Mohawk
- ...

Each provider has its own electricity price schedule
- Ex: Nantucket Electric

Nantucket Electric rates depend on peak power and total energy draw:
- Estimating peak power \(\Leftrightarrow\) Estimating number of chargers required
- Number of chargers \(\Leftrightarrow\) Number of aircraft that can be recharged simultaneously
Way Forward and Collaboration…

• Extend computation of energy prices to each airport in case study networks:
  – Estimate peak power at each airport per day
  – Estimate total energy need at each airport per day

  Requires collaboration with operators to analyze network schedules, track aircraft tail-numbers, estimate turn around times, and estimate number of simultaneous battery charges

• Analyze impact of DEP aircraft on operations:
  – Impact on turn around time
  – Impact on rotations of crews
  – Impact on maintenance reserves

  Requires collaboration with operators to fully understand multi-faceted operational considerations and constraints

• Optimize and refine DEP thin-haul concept of operations to improve operating costs, e.g. optimization of battery charge strategies to mitigate impact on utilization and to reduce electricity rates
Questions?