Cross-Directorate Forum 4.0
Distributed Electric Propulsion: Opportunities and Challenges

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CDF 4.0

- Purpose:
  - Address both opportunities and challenges associated with distributed electric propulsion, from UAVs to general aviation to regional transports

- Desired Outcomes:
  - Foster conversation amongst members of the greater NASA technical community, particularly between the vast majority who are not working DEP and those who are
  - Generate new ideas leading to practical solutions

Introduction and Overview

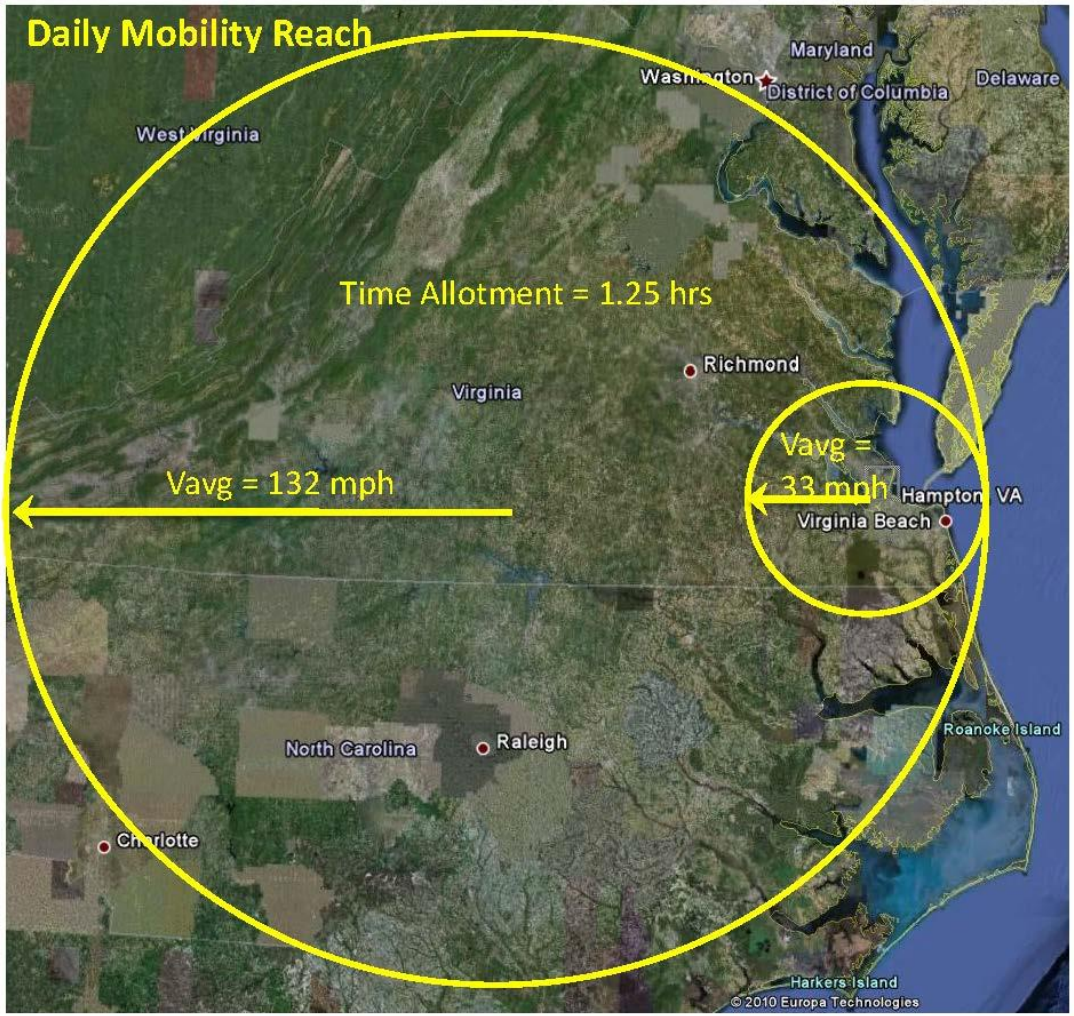
- On-Demand Mobility

- History
  - Early Days
  - Distributed Electric Propulsion Beginnings
  - Spiral Development

- CDF 4.0
  - Purpose & Desired Outcomes
  - Agenda

Transformational On-Demand Mobility

What if the average ground speed of 33mph could be increased to 4x faster?



Regional Impact

Alternative to 1-D ground highway congestion

Geographic constraints are removed (mountains, bridges, rivers, …)

Scarce resource constraints are removed (housing cost…)

Combined with telecommuting, remote land areas become quickly accessible alternatives

Existing On-Demand Mobility Solutions

Current GA and UAV Aircraft

Poor Aerodynamic and Propulsive Efficiencies

Poor Community Noise

Poor Comparative Safety

Poor Emissions

Poor Control Robustness and Ride Quality

High Operating Costs

Significant Training Requirements

Autonomy and Distributed Electric Propulsion have the potential to dramatically improve all of these capability gaps.

History – Early Days (2009)

- Combination of IRAD and OGA funding
- Enough to raise some interesting ideas including the Puffin VTOL PAV

History – DEP Beginnings (2009-11)

- Systems studies supported by NASA Strategy, Architecture and Analysis Office
- Investigated a number of concepts including ZIP aviation which utilized advanced technology small aircraft to provide high speed regional mobility.
  - Autonomy and electric propulsion identified as critical technologies
- Subsequent work pointed to DEP as best way to integrate technologies for impact on the configuration
  - Retrofit model not the way to go
  - Studies in Europe and Rolls Royce point to DEP configurations

History – DEP Beginnings

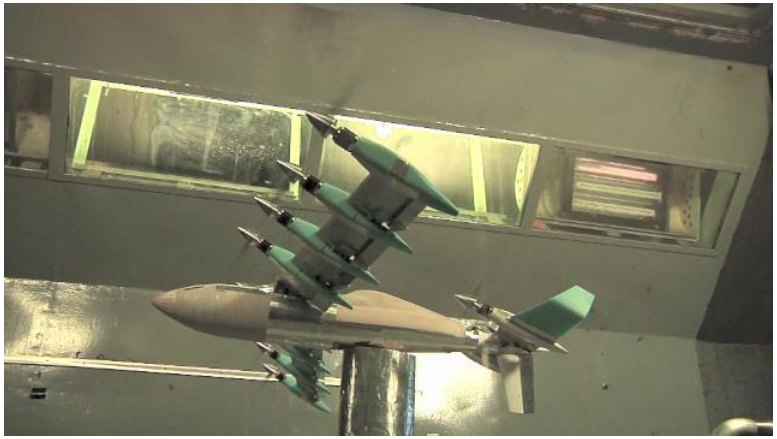
- DEP opens most degrees-of-freedom to the disciplines
  - Aero-propulsive
    - High lift, smaller wing, higher wing loading giving smoother ride, higher aerodynamic efficiency
  - Aeroacoustics
    - Low noise designs tailored to minimize community noise annoyance
  - Flight controls
    - Reliable, robust & redundant control using distributed thrust to create control forces & moments
  - Autonomy
    - Not fundamentally enabled by DEP but convergent to DEP's digital control systems

Early work was aero-propulsive centric and highlighted need to start working in multidisciplinary manner

History – Spiral Development

- Unmanned demonstrators (2011 – Present) (OGA)
  - Joby Lotus (DEP VTOL)

  - NASA GL-10 DEP Tilt-Wing



History – Spiral Development

- Large scale DEP demonstration (2012 – Present) (ARMD Team Seedling, AFRC & Joby)
  - Hybrid Electric Integrated System Testbed (HEIST)
    - Validate highlift performance of the DEP wing on a custom tractor-trailer testing rig.

- 31-ft span wing with 12 motor/propellers
- 360 hp with testing at 61 knot stall speed
- 1st Run – late December/early January

History – Spiral Development

- First Manned Flight Demonstrator (2015-18) (CAS Project)
  - Uses Leading Edge Asynchronous Propellers Technology (LEAPTech) wing

- Retrofit of Tecnam P2006T wing with LEAPTech wing provides low cost flight demonstration path with direct comparison to reference baseline flight data

DEP Manned Flight Demonstrator

CDF 4.0 Agenda

- DEP Spiral Development: UAVs to General Aviation to Regional Transports (Mark Moore)
- DEP Analysis, Design, and Certification Challenges (Nick Borer)
- Perception-Influenced Acoustic Design of DEP systems (Casey Burley)
- Reliable, Robust and Redundant Flight Controls for DEP systems (Irene Gregory)
- Group Discussion