Are Practical Electric and Hybrid Airplanes Just Around the Corner?
(post-presentation slides; more detail in accompanying outline)

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Are Practical Electric and Hybrid Airplanes Just Around the Corner?

There are good reasons for electric airplanes ASAP

- **Cost**
  - At the shaft, electricity is less than 1/5 the cost avgas
  - Though batteries are hugely expensive, so are the aircraft engines they can replace

- **Noise – an increasing problem at GA airports**

- **Aircraft engines pollute**
  - Aircraft piston engines have not been cleaned up at all. In contrast, new auto engines are around 200x cleaner than before, making each piston aircraft a ‘gross polluter’ in comparison
  - 100LL is now actually on its way out, due to airborne lead near GA airports
  - Particulates, hydrocarbons, oxides of nitrogen, etc, must eventually be regulated
  - Studies show that electric power is cleaner than the best of today’s auto engines

- **Electric airplanes will immediately be lower carbon**
  - Because 2-3 times as efficient as ICE
  - Average U.S. electricity now higher CO2 per kWh than gasoline, but not for long
    - CA already twice as low
    - Many states have renewable portfolio standards – soon the U.S?
  - Plenty of electric capacity available
  - Hangars could be covered with solar panels
  - Low carbon biofuels will have limited availability for the foreseeable future

- **Reliability – potentially much higher, though not yet proven**
  - Potential to be safer than twins, which don’t actually have a better engine-out safety record than singles (due to loss of control from sudden off-axis thrust)
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What minimum performance is needed for a practical electric airplane?

• My guesses as a GA pilot & former C-172 owner
  – For some, not all pilots
  – Not what’s competitive without fuel & environment considerations
  – Endurance bladder-limited to 3 hours anyway
  – Cruise speed and endurance rated at sea level (SL)
    • Endurance rated at the same cruise speed
  – Refueling will depend upon
    • As-yet-nonexistent charge stations, or
    • A high-power electrical outlet available via pre-arrangement
Recreational Flying

• **Local flying** – near C-150 or LSA performance
  – 1-2-place, 200 lb/person (200-400 lb) payload (no baggage)
  – 100 mph/87 kt cruise, 8k ft ceiling
  – 1.5 hours endurance at cruise + VFR reserve
  – Overnight refueling, except <1 hr for rentals

• **Day trips** – near C-172 or LSA performance
  – 2-4-place, 225 lb/person (450-900 lb) payload
  – 100+ kt cruise, 10k+ ceiling (12k+ in the West)
  – 2-3 hours endurance (230-345 mi) + VFR or IFR reserve
  – 4 hours maximum to refuel

• **Long distance cross-country flying** – C-172++
  – 2-4-place, 250 lb/person payload (500-1000 lb)
  – 100-200 kt cruise, 12k+ ceiling
  – 2.5-3 hours endurance (288-690 mi) + VFR or IFR reserve
  – 1 hour max to refuel (time for a meal)
• **Business Travel**  
  – Single-person travel, a stop after each leg  
    • Like recreational day trips, except  
    • 1-place, 250-500 lb payload (may include equipment)  
    • 1-2 hours maximum refuel time due to multiple legs  
    • More speed is highly desirable, as time is money  
  – **Carrying clients or associates, a stop after each leg**  
    • Like single-person business, except  
    • 3-4-place, 250 lb/person (750-1000 lb) payload  
  – **Long distance cross-country flying**  
    • Like recreational, except IFR reserve and 150+ kt cruise  

• **Commuting**  
  – 1-2-place, 225 lb/person payload (225-450 lb), 100-150 kt cruise  
  – 2-2.5 hours (more is too long a commute) at cruise (230-375 mi) + IFR reserve  
  – 6-8 hours to refuel during work
What can hybridizing an airplane accomplish?

- **Suggested/modeled hybrid**
  - Parallel, powered by the electric motor and/or the engine
  - Motor always turns, direct or via a PSRU
  - Engine, attached via a centrifugal clutch, can start & stop
  - Enough electric energy to climb to e.g. 10k ft
    - Ground (PHEV) charging enables some fuel displacement
    - A reversing propeller can capture energy during descents

- **Quiet airport operations**
  - Except when full power needed for short field or high altitude takeoffs

- **Smaller, lighter, efficient Diesel engine**
  - Sized only for cruise power (especially DeltaHawk)
  - Higher efficiency also means less weight for fuel

- **Some electric energy is always held in reserve for an emergency**
  - For long life, normal discharge is by only 80%
  - Fewer engine-failure-induced fatal crashes
  - Electric power is more reliable, and dual-power is more reliable yet
For both electric and hybrid, I started with the fastest 4-place piston kit airframes

- Kit airplanes get registered as amateur-built experimental
  - Modifiable and can be flown most anywhere
  - Must be efficient to be fast
  - Maximum L/D occurs at usefully fast speeds
  - 2 places and associated payload can be sacrificed for sufficient range with today’s batteries
  - As batteries improve, will the airframe remain near optimum for increasing either…
    - Cruise speed and range, or
    - Payload?

My modeling (live spreadsheet to follow)
### Are Practical Electric and Hybrid Airplanes Just Around the Corner?

A worksheet for possible electric aircraft to enter the NASA/CAFE high-efficiency 2-place airplane contest by Ronald Gremban, latest version, 4/24/2009.

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<th>Velocity XL N/H S/C Electrical/RDF power</th>
<th>Longitudinal S/C Electrical/RDF power</th>
<th>Longitudinal S/C Electrical/RDF power + drag</th>
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