Electric Flight

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To reduce emissions, we need to stop burning carbon fuels

And at first look, electric propulsion is more efficient…

Internal Combustion

- Engine efficiency ~ 20%
- Prop efficiency ~85%

0.2 x 0.85 = 0.17

Total efficiency ~ 17%

All electric

- Battery charge efficiency ~85%
- Brushless motor efficiency ~90%
- Prop efficiency ~85%

0.85 x 0.9 x 0.85 = 0.65

Total efficiency ~65%

x 3.8

However

The best Lithium-Ion (rechargeable) batteries: 225 Wh/kg

A tank of Avgas: 13,100 Wh/kg

13,100 / 225 = 58.2

58.2 / 3.8 = 15.3

So our energy is 15 times as heavy with (best available) batteries as with typical liquid fuels

On the bright side

Weight of a typical 80hp (60kW) engine (Rotax 912): 60kg

Weight of a lightweight 60kW motor + controller (Geiger HP50D) : 25kg

35kg = about 3hrs fuel in a Rotax 912.

What technologies do we have?

BATTERY ELECTRIC

CONVENTIONAL

FUEL HYBRID

FUEL CELL

(with or without hybridisation)

An aside – every solution uses propeller(s) – so the future is probably slower, not faster.

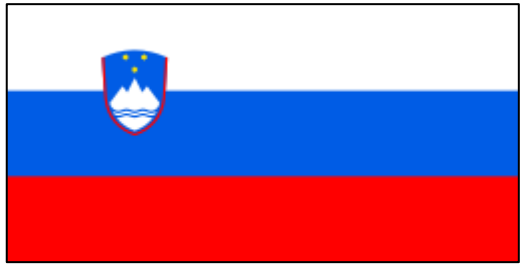
RR Electroflight ACCEL

VoltAero CASSIO-1

ZeroAvia HyFlyer-1

These have all flown, also…

The world's only certified electric aeroplane (Pipistrel)



Britain is on catchup

Sherwood eKub

Little Snoring

Ground testing Sherwood eKub
– and putting to bed the notion that electric aircraft will be silent

Fundamentals of approval to fly aircraft

- Requirements to comply with ICAO declared standards
  - Part 23 aeroplanes to 19 passenger seats
  - Part 25 large aeroplanes
  - Part 27 helicopters to 9 passenger seats
  - Part 29 large helicopters
- These standards don’t presently encompass new energy technologies
  - Drop-in fuels may short cut
  - Most other technologies need major research effort

Onboard storage electric technologies and implications

Technology	Primary Aircraft Implications
Batteries	About 14 times heavier in use – only feasible for sports and training aircraft with current technology. Also completely new systems of operation, certification, planning.
Gaseous hydrogen	New airframe shapes to accommodate large tanks. Hydrogen embrittlement of components. Fuel cell aging. Potential use of tankering, not presently wise.
Liquid hydrogen	Totally new fuel storage and cooling systems Move from TRL5-6 (ZeroAvia Hyflyer) to TRL8-9
Hybridisation	New powertrain technologies New operating paradigms Potentially useful splits of mission and reserve energy.

Mission versus reserve energy

- Example Jersey (EGJJ) to Guernsey (Jersey)
- 24 nautical miles, about 15 minutes energy
- Safety reserves for..
  - Go-around
  - Diversion to airfield in France (~30mins)
  - Plus 30-45mins additional
- So mission batteries + reserve fuel may be feasible
  - Totally new regulatory ground
  - Yet more research needed here!

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Ground Support Infrastructure #1

- Electrical Power Grids or energy source distribution
  - Massive upscaling of any capability
  - Electric grid, hydrogen distribution, SAF distribution..

- New fuel energy storage
  - Presently only AVTUR (Kerosene) and AVGAS (Petroleum) storage at airports
  - Major additional facilities for any additional fuels
    - Aviation standards for these mostly don’t yet exist.
  - Battery transfer and storage
    - Required for electric or hybrid
    - Totally new questions to solve

Ground Support Infrastructure #2

- Fire and Rescue
  - We do not yet know fire and rescue requirements for new fuels on aircraft
  - Would require development of new capability at every served airport.
    - Plus civil fire services?
  - Analogous to introduction of composite airframes

- Basic airport infrastructure
  - We are still in the 1950s with shapes and equipment

(Tampa, FL)

The Human Requirements

- Every skillset will be affected
  - Pilots
  - Cabin Crew
  - Maintenance
  - Refuellers
  - Firefighters
  - Quality Assurance
  - Regulators
  - Dispatchers

- Just about everybody except the padre and the chef !

- Science must deliver on the knowledge requirements.

Further consideration: Technology Waves

- There will not be a single step in technology

- The following is feasible, but <u>not</u> a prediction
  - 2020-2030 Sustainable fuels for all aircraft
  - 2028-2040 Hybrid-electric for small/short range
  - 2030-2045 Hydrogen (pure or hybridised)
  - 2035-2050 Ultra high density batteries
    - Unobtanium: 5-15 times better than at present?

- Perspective
  - 1903 Wright Brothers first flight
  - 1939 First jet flight (36 years from Wright Brothers))
  - 1949 First supersonic flight (10 years from first jet flight)
  - 2020 World's first ICAO Certified electric aircraft
  - 2050 – 28 years to go.
    - Unobtanium may happen.
    - Net Zero air transport 2050 is feasible. **There won't be quick cheap solutions.**


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