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Electric Flight
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Our speaker commented that this was his first lecture to an audience for almost two years. However, he still knew how to ensure that we received a description of relevant research and practical work. The content presented aspects of the aeronautical and engineering of electric propulsion, and experience of piloting several research aircraft.

He asked why do we need electric flight? It has become an essential objective to avoid air pollution but that is not possible using conventional piston and jet engines. The target set for designers is to attain zero carbon emissions in aircraft exhausts by 2050. Regulations are looking for improvements of carbon dioxide (CO_2), ozone (O_3), methane (CH_4) and water (H_2O). The latter is related to the generation of contrails. Meanwhile, a 50% overall reduction of emissions has become a design target for 2030. The thermal efficiency of current light aircraft engine/propellor combination is about 17%, and equivalent electric engines being tested already are expected to improve thermal efficiency to 65%.

According to scientists the 'obvious solution' is to not use fossil fuel, and to carry energy in batteries. There is a problem in the comparison of the options. Current Lithium-Ion batteries (that are rechargeable) produce 225 Wh/kg energy, whereas Kerosene can produce 12,000Wh/kg. Electric energy is heavier than fossil fuel and the weight does not change throughout a flight. Batteries have to be installed evenly fore and aft and from left and right relative to the aircraft centre of gravity (c.g.). This is not unique as there is a similar requirement for fossil fuel tanks, but they need a fuel system that monitors fuel movement to maintain an even fuel distribution relative to the c.g. as the fuel mass reduces.

A typical light aircraft engine using fossil fuel (Rotax 912) weighs 60kg and delivers 80hp (65kW). An equivalent electric engine (Geiger HP50D) motor and controller weights 25kg. For the latter, there is a choice of three types of battery technology

(1) *Battery Technology:* the basis of aircraft such as the proposed Eviation Alice.

(2) *Conventional Fuel Hybrid:* battery and conventional engine

- VoltAero's CASSIO aircraft having displayed a 17% fuel mass saving

(3) *Fuel Cell:* hydrogen-based, for example the ZeroAvia Hyflyer-1 based upon a Piper PA46

The only certified electric aircraft is the Slovenian Velis Electro Pipistrel, and the Rolls-Royce ACCEL is the most powerful demonstrator flown already. The company test pilot set the speed record for an electric powered aircraft in 2021.

There is a Nordic Air Race Team that has reached 140kts, but on the first flight 50% of the available battery capacity was used in 8 minutes – certainly short of desired endurance, but plenty of extra capability is likely soon, as more efficient systems are being developed.

International legislation for the airworthiness of electric aircraft will evolve, and it will be managed by an extension of existing airworthiness organisations. Our speaker is involved in a team of experienced electric flight teams in the UK and Europe where members have set out to develop design and airworthiness standards that will support all electric flight projects. The aim is to ensure that existing safety requirements of the standards already used for light aircraft certification will be equalled or bettered. Much of the initial work has been undertaken by a consortium based in the UK. The initial members of the team are:

Flylight - a microlight aircraft manufacturer (Sywell)

TLAC - a microlight aircraft manufacturer (Little Snoring)

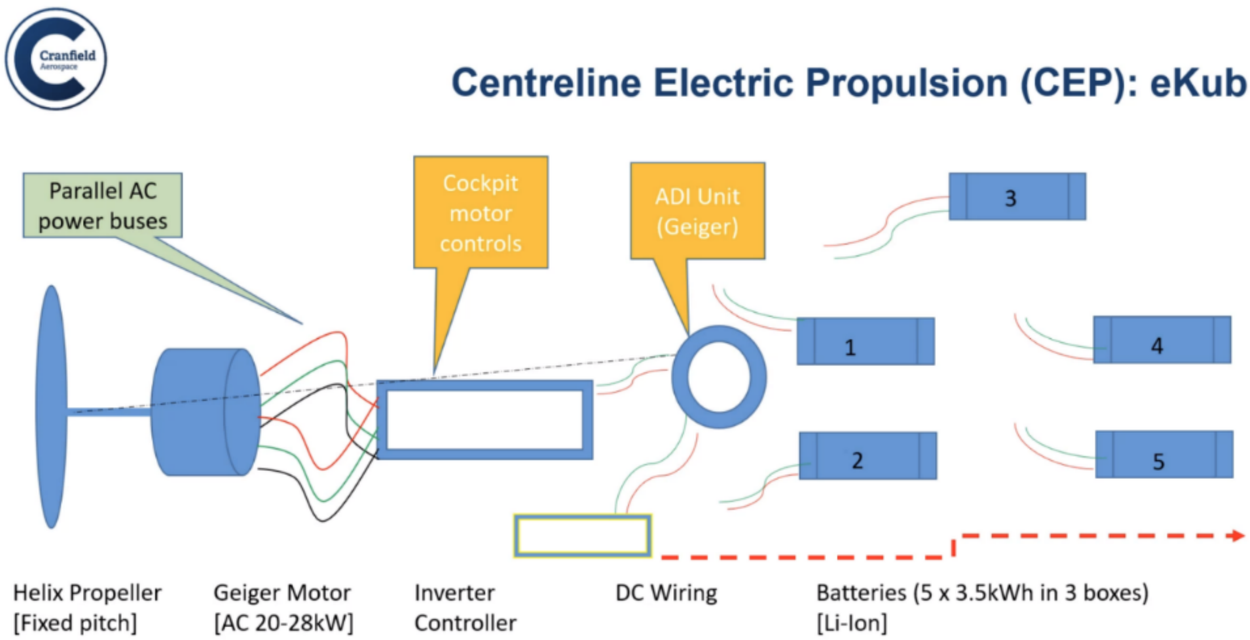
CDO² - a battery technology company (Sussex)

Cranfield - aircraft design requirements and testing (Cranfield University)

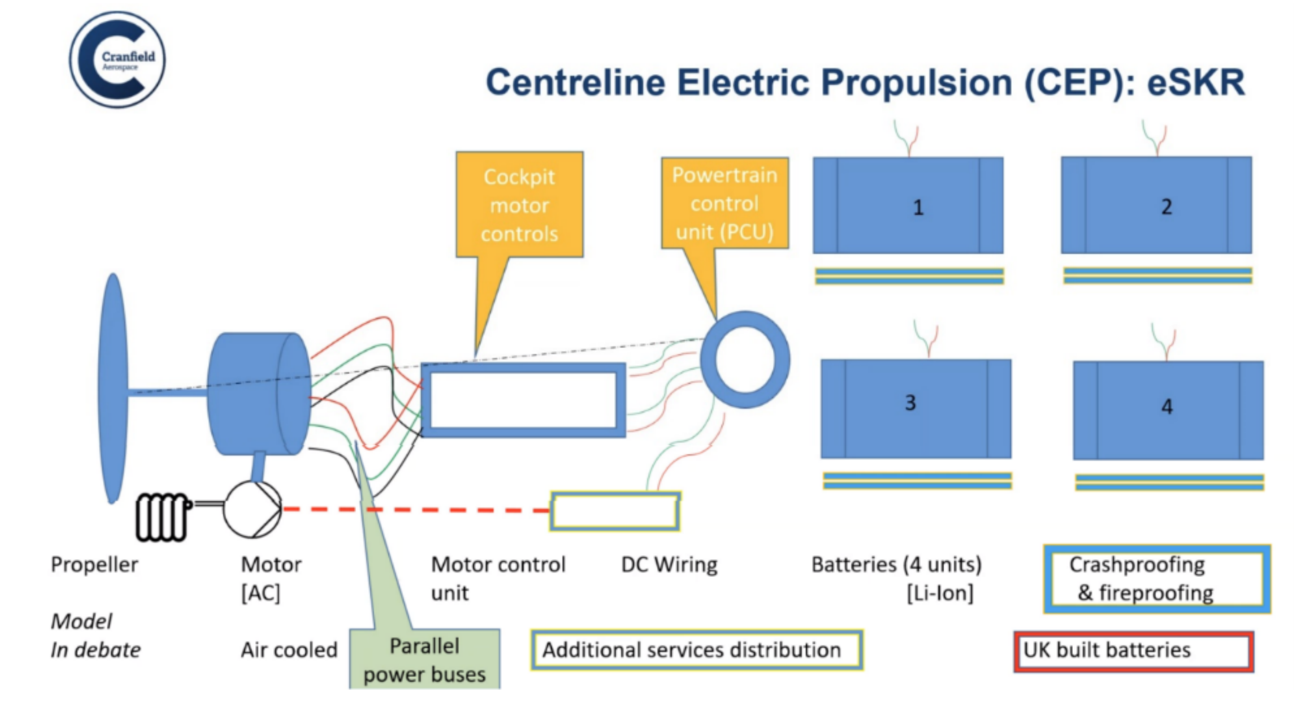
They refer to 'enabling aircraft electrification' as their overall aim and have set out a programme for any newcomers to adopt and contribute to the rectification of emerging parameters. The speaker, being a qualified test pilot, has flown in aircraft at his base, Cranfield, at Sywell and also at Little Snoring.

The team is addressing build, test, certification, operational and training requirements. This has required practical experience, ground testing and flying. Practices and procedures are akin to those applied to existing light aircraft. Two aircraft are being used, these being the eKub aircraft developed at Little Snoring (Norfolk) and an eSKR developed at Sywell.

Ground run of the eKub with centreline electric propulsion (CEP) system at Little Snoring. (CEP system diagram below)



Build stage of eSKR with centreline electric propulsion (CEP) system at Sywell. (CEP system diagram below)



Objectives of the work underway have been considering how legislation for now designs will relate to Zero Carbon requirements, and what requirements (infrastructure and operations) will be essential for electric aircraft manufacturers and operators. Procedures are being proposed that address aircraft build, testing, certification, operations and pilot training.

Regulators uphold redundancy in safety related aspects and have to justify a balance of safety and complexity, which was summarised in the presentation using a chart. One topic specifically considered was battery redundancy, given that EnabEl's experience is that batteries can if required generate about 40% more power than their standard design case for short periods. The more battery packs that are used, the greater is the redundancy, but the more complex is the system.

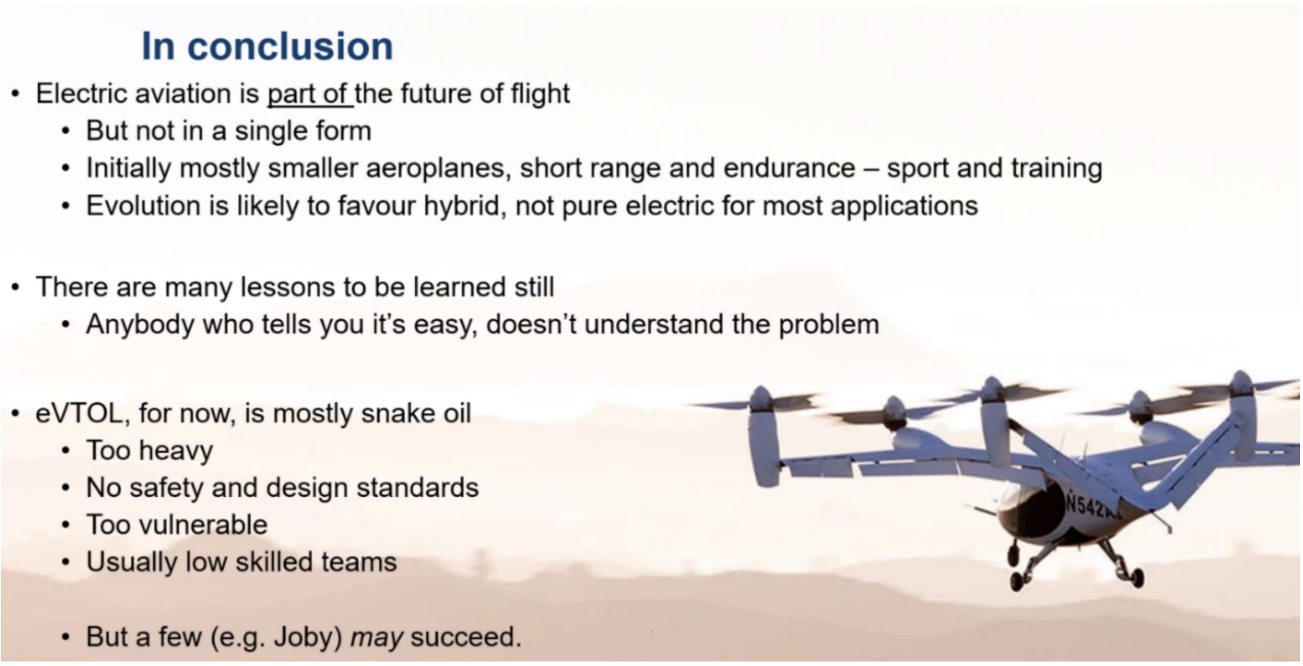
➢ A single battery pack single failure causes a total power loss

- ➢ Two battery packs - one failure will cause 50% power loss (30% thrust), and a double failure causes full power loss
- ➢ Three battery packs – single failure causes 33% range and endurance loss with 5% thrust loss. A double pack failure causes 67% power loss, range and endurance with 54% thrust loss
- ➢ Four battery packs - single failure causes 25% range and endurance loss and there is no thrust loss. A double pack failure causes 50% power loss, and 30% thrust loss
- ➢ Five battery packs – single failure causes 20% range and endurance loss, and no thrust loss. A double pack failure causes 40% range and endurance loss and 15% thrust loss.

The aircraft used in trials: eKub has 5 battery packs, and the eSKR has 4 battery packs. The Velis Pipistrel, the world's only certified electric aircraft, has a 2 battery pack system.

Velis Pipistrel – developed in Slovenia

The speaker commented that the UK evaluation team believes a two-pack system may not have sufficient redundancy, because of likely safety requirements applicable to training applications, and long-range flights.



This meeting's presenter, whilst introduced as an academic, revealed interest of not just technology and environmental constraints. He showed how environmental and safety requirements for light aircraft, fundamentally akin to what is being imposed on airliners, are presenting challenging design requirements. He is working alongside people set to changing light aviation aspects, by being involved in the design, development and testing of this new category of aircraft.

He made everyone aware of the scope of issues that will be tested to meet operations, design, and safety requirements in the future, and held the attention of our audience. He can expect to find many more enthusiasts who will be as engrossed as the 90+ attendees.

Lecture notes by Mike