

Preparing for electric flight

In recent years the pace of change in new technology has often meant that standards and regulations have to be developed after the product or process is ready. However, in the case of passenger-carrying all electric aircraft, the regulators are hoping to keep pace to smooth the way for their introduction. **BILL READ FRAeS** reports.



Solar Impulse 2 flew around the world in 2015-16 using only solar power. (Solar Impulse)

Following widespread publicity generated by the 40,000km round the world odyssey of the Solar Impulse 2 experimental solar-powered aircraft in 2015-2016, one of the most asked questions from the general public was: 'When will we see the introduction of large passenger-carrying electric powered aircraft?' The answer given by informed experts who knew something about the research and technical advancements still needed before commercial electric aircraft become a practical proposition was 'no time soon'. However, while the first commercial passenger flight on an all-electric aircraft is still some way off into the future, that development of electrically-powered aircraft has begun to move much faster than was originally anticipated.



ElectraFlyer Trike electrically powered microlight. (ElectraFlyer.com)

The past ten years has seen the development of a series of new electrically-powered aircraft, powered either by batteries, solar cells or a combination of both. These new aircraft have included solar-powered UAVS (QinetiQ/Airbus Defence Zephyr), power-assisted gliders (EGenius), fixed-wing light aircraft (Taurus G4, EADS/Airbus Cri-Cri and E-Fan), ultralights (ElectraFlyer Trike), multiple rotor rotary wing (Volocopter) and even a VTOL jet (Lilium).

Up to now, all these electrically-powered aircraft have been relatively small in size, either being unmanned or only able to carry a limited number of people. However, plans are now afoot to develop much larger electric-powered aircraft. Airbus has abandoned plans to develop production GA versions of the E-Fan, to work on a project to develop a hybrid-electric version of a BAE 146 regional jet as the E-Fan X technology demonstrator. Meanwhile, Boeing is one of a number of companies supporting Zunum Aero in its development of a hybrid business aircraft.

More-electric aircraft



Technology used in more-electric aircraft, such as the Boeing 787, is paving the way for all-electric designs. (Boeing)

Meanwhile, the development of small electric aircraft has been accompanied by technological upgrades to larger commercial aircraft in which electrically-powered systems have been used to replace equipment previously powered by bleed air from the engines, including cabin pressurization, air conditioning and de-icing. Electric power is also being used to replace pneumatic and hydraulic systems, such as flight controls, brakes and landing gear. Electric motors can also be used to power wheels to enable an aircraft to perform its own pushback and taxiing without the need for an external tug. One of the major pioneers of these 'more-electric aircraft' systems has been the Boeing 787 which uses electric systems to replace those previously powered by hydraulics or bleed air from the engines.

The dead hand of regulation?

A complaint often heard in discussions about new aerospace research and technology has been the slow development of regulations. While new technology can develop at a fast pace, the time needed to develop new

production standards and introduce new safety and certification rules by the regulators which will actually permit the new product or process to be used in a commercial aircraft are much slower. Examples of this in the aerospace industry have been seen in the development of composites, 3D printing and in flying cars.

Standards to the rescue



Airbus E-Thrust hybrid-electric airliner concept (Airbus)

However, in the case of fully-electric aircraft, the standards and regulatory authorities are planning to keep pace with the 'cutting edge' of technology, to help co-ordinate their development and reduce the time needed for their introduction into service. One organisation current very active in the development of electric aircraft is SAE International, an international global standards developing organization that 'advances self-propelled vehicle and system knowledge in a neutral forum for the benefit of society'. The organisation is active in the aerospace, automotive and commercial-vehicle industries. In addition to setting standards for industry engineering, SAE also encourages a 'lifetime of learning' for mobility engineering professionals. Comprised of 127,000 scientists, engineers and technical experts, SAE claims to have facilitated the development of global standards for the aerospace industry since its introduction of the first interchangeable

spark plug standard.

David Alexander, Director of Aerospace Standards at SAE, explains how the organisation is helping to pave the way for electric aircraft: "While standardisation may not be seen as one of the most exciting aspects of aviation, it is becoming more high profile, as it is more used and needed by the regulatory authorities. Certification authorities are looking towards more performance-based industry standards and industry is playing a much greater role in the regulatory process. Rather than waiting until a product is mature and then describing it, industry is using the standardisation process to develop a consensus on practices and standards for technology that is not yet proven. It's an environment in which industry is working collaboratively with various industry stakeholders, regulatory authorities and responsible military agencies."

"One of the great things about our work is that we have the regulators and industry together. Regulators such as the European Aviation Safety Authority (EASA) are very keen to meet industry as early as possible in the process to hear what they're looking at and what they're hoping to do and then starting thinking about whether the existing regulatory framework and existing rules will allow them to address that or approve that particular technology or product or whether they should start thinking of something a bit more creative."

"To give the example of additive manufacturing, industry was working on certain things and regulatory authorities knew that they had certain rules governing materials and structures but perhaps weren't sure exactly how they would go about certifying something where there was less certainty about the outcome. The US Federal Aviation Administration (FAA) made a request for the SAE to set up a new technical committee on additive manufacturing so we could develop some technical specifications that they

could then use in their certification work.

Sharing knowledge

There are sometimes problems when companies researching new technology are not keen to share their findings with each other which may result in duplication of effort. "That is definitely an issue," agrees Alexander. "It's natural. Technology developments in industry will happen at a different pace with different objectives depending on the organisation and their ambitions. There's always a sweet spot in standardisation where it's early enough in the development of a particular technology, product or process for the standardisation process to be used in a very productive way for the industry to set out some basic principles that will enable all of them to be faster, particularly when you're looking ahead to certification but late enough in the process that companies are willing to come together and sit round the table and share what they have with partners, customers and suppliers. Different companies have different cultures regarding intellectual property (IP) and sharing. This will also depend on different innovation imperatives.

Steering towards electric aircraft



E-Genius electric aircraft. (Andreas Doerr)

To facilitate the development of new commercial electric aircraft, SAE International has created the Electric Aircraft Steering Group (EASG). The Group meets online every month and twice a year face to face and includes representatives from major aerospace companies and organisations, including Airbus, Boeing, Bombardier, Embraer, EASA, FAA, GE, Honeywell, Lockheed Martin and Rolls-Royce. The aim of the Group is to: 'strategically identify, landscape and co-ordinate the various standardisation activities necessary to support full-electric and more electric aircraft applications at the top level system, subsystem and component levels.'

Currently, the EASG is working on defining the 'standardisation landscape' needed to support the power and infrastructure 'backbone' for electric aircraft and system functions, to develop a matrix of existing or in-progress standards which will highlight where work is still needed and to liaise with existing standard developing committees. Currently, the EASG is looking at such subjects as types of vehicle, energy and power storage, hybrid/electrical propulsion, more electric engines, safety, power generation, maintenance, operations, testing, controls, power electronics and modular open architecture. "Our future work includes defining a roadmap for new standards needed and how existing or new SAE committees can help develop them," says Alexander.

Work in progress



Electric brakes on Bombardier's CSeries are another example of the shift towards more-electric aircraft. (Bombardier)

The development of larger all-electric aircraft is already well advanced. "The more that people are working on the 'more-electric' systems, the more progress we are making towards an eventual 'all-electric' aircraft," said Alexander. "We already have many electric systems on aircraft, including electric actuators for flight controls, brakes and landing gear, as well as (on bleedless engines) APU start, cabin pressurisation, engine start and ice protection systems. One recent example are the electric brakes on the new Bombardier CSeries regional jet. Bombardier says that these brakes have proved more reliable compared to hydraulic systems - which is very promising for the future.

"We've already started with the use of electric power in more-electric aircraft," says Alexander. "Already we've produced reports, recommended practices and some standards on such topics as higher voltage applications, electric braking and electric acuation.

The shape of electric aircraft to come

While it is not the purpose of this article to look in detail how a future all-

electric aircraft might look, the current focus of the SAE's deliberations does provide some general pointers.

It is likely that the engines will be mounted in different places on the wing or fuselage with, possibly, a number of multiple 'distributed power' electric engines. The electric engines will turn propellers which will make the aircraft fly slower than a jet aircraft.

Power of the sun?



Artist's impression of future Zephyr solar-powered UAVs. (Airbus)

Where will the electricity come from - from batteries or from solar-electric cells? "Currently, it's likely to come mostly from batteries," says Alexander. "Power generated from solar cells is limited by the amount of surface area you can fit them onto and also the availability of sunlight. A commercial electric aircraft will have to fly at night as well as in the day."

The shape of the wings is also under discussion. Pure solar-powered aircraft such as the Solar Impulse 2, were fitted with very long thin wings designed both to keep the aircraft aloft and to maximise the number of solar cells. However, such long straight wings would make an aircraft very slow and also have a very wide wingspan which might not fit into a conventional airport gate. "Airport space is going to still be at a premium," said Alexander.

Hybrid aircraft



Airbus E-Fan Plus hybrid-electric aircraft on display at the Oshkosh air show in 2016. (Airbus)

As more research is conducted into larger electric aircraft, one factor that is becoming clearer is that the first passenger-carrying designs are unlikely to rely solely on electric power due to safety considerations. What happens should the batteries run out or fail to work? How could an electric aircraft cope with a longer route diversion as a result of an airport or airspace closure? There is also the problem that aircraft need to use a lot of power for take-off and climb out which would take a lot of power from the batteries at the beginning of a flight. It would also take longer to reach take-off speeds, so an all-electric aircraft might require a longer runway.

Because of these concerns, current research is focusing on 'hybrid' designs which would also have conventionally powered engines as well as electric engines. Because a hybrid aircraft does not rely on one source of power, it would be easier to certify from a safety point of view. "The need for redundant systems is certainly there," says Alexander. "No matter how proven battery technology is in 15 or 20 years, you've still got that ability to switch should anything happen.

An example of a hybrid design can be seen with Airbus' development of the

E-Fan into the hybrid power E-Fan Plus which flew in the summer of 2016. Fitted with a thermal combustion engine in the rear cockpit that can generate enough electricity to sustain the E-Fan Plus in level flight at maximum cruise speed in addition to charging its lithium-ion batteries.

Size is everything



Airbus E-Fan 2.0 and A380. Electric aircraft will get bigger but not that big. (Airbus)

Another characteristic of a future all-electric aircraft would be its size and range. Current research suggests that, while electric propulsion is feasible for larger aircraft, there is an upper limit beyond which they would become technologically and economically impossible. "At the moment we are only focusing our attention on medium-sized short range aircraft," said David Alexander. "Nothing that I've seen or heard suggests that industry would be confident to develop anything above a short-range regional aircraft running with some form of hybrid power. While the E-Fan is propelled by two 60Kw power fans, a 747-sized aircraft would need up to 90Mw to take-off, which one of my colleagues has calculated would need a power equivalent to 4m laptop batteries."

Another question is whether a large electric-powered aircraft would need to

have separate power sources for the engines to keep the aircraft flying and to power the internal systems. "That's a good question and I'm not sure we can say right now what the safety criteria is likely to be," admits David Alexander. "Having a system in which power can be shared between these two functions is going to be advantageous but how it's going to be done has yet to be confirmed."

Where do the batteries go?



Eviation's electric-powered commuter aircraft, Alice, is a sleek design - but where do the batteries go? (Eviation)

Another area of research is where the batteries to power the aircraft might go. Should they be in the wings - where jet fuel is stored in conventionally-powered aircraft - or in the fuselage. In a hybrid powered aircraft, batteries in the wings would make the wings heavier and space there might still be needed for liquid fuel while storing batteries in the fuselage would take up space which could be used for seating passengers or storing luggage. David Alexander says that the answers to such questions still lie in the future. "The jury is still out there in terms of what the manufacturers want," he said. "At present we're not particularly concerned with how the shape of the aircraft might look but we are interested in are safety and

operational considerations. Should the batteries be recharged in situ on the ground or taken out to be replaced by fresh batteries? How easy will it be to install or remove batteries for recharging? In terms of battery life, it is better to have a slower recharge to maximise battery life. Recharging the batteries within the aircraft will take time and low-cost operators like to utilise aircraft several times a day."

"We also have to consider the concentration and proximity of batteries to other critical systems. Currently, our standardisation work is looking at environmental and installation requirements rather than on physical fitting. While operators and manufacturers would eventually like to have a choice of interchangeable batteries, that is a later consideration."

Battery safety

Related to this issue are concerns over battery safety, particularly with high energy batteries such as lithium ion which run the risk (as was evident in the early days of the 787 in service) of catching fire. "A lot of work is being done now to ensure the safety of batteries," assures David Alexander. "The 787 did have problems with lithium batteries and that is still a concern. It's not so much that the battery technology itself is not safe but the way they are used. The battery manufacturers are working hard and we have hope and expectation that they will find a solution. Interestingly, one of the most high profile activities that we've been working on over the past couple of years is looking at the transport of lithium batteries in air cargo and ICAO asked us to develop a packaging standard for which we are hoping for a final draft by the end of the year."

One area that SAE is not directly involved in is testing the effect of adverse weather or flight conditions on batteries or electric motors. "There is a very robust testing and certification procedure but that's not something that

we've been party to," admits Alexander. "The question is whether this will prove sufficient to prove with any degree of assurance with electric configured aircraft."

Technology breakthroughs needed



All-electric aircraft will need to be both technically and economically feasible. (Zunum Aero).

However, the development of standards cannot guarantee the creation of larger electric-powered aircraft. The development of such aircraft also depends on the development of new technology which does not yet exist, including major improvements in the energy density of batteries and even high efficiency, more powerful electric motors capable of producing jet-like propulsion. "New designs will depend on new batteries being developed which do not exist at present," says Alexander.

Other technical advances are also needed in cooling technologies, high power density electronics and new high temperature-resistant lightweight materials.

But will they make money?

A final important factor is that of economics. Not only must a commercial electric aircraft be safe to fly, it must also make money for an airline. "Investing in a completely new paradigm for air travel must make economic sense," said Alexander. He admits that current low oil prices are not helping. "Talking to people in the industry, there is obviously a lot of thrust towards electric aircraft when fuel price is high," he says. "With low oil prices, fuel consumption is less of an economic driver and an all-electric aircraft is not currently going to be competitive. However, this may change in the future as fuel becomes more expensive."

Bill Read

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