ROYAL AERONAUTICAL SOCIETY
LOUGHBOROUGH BRANCH

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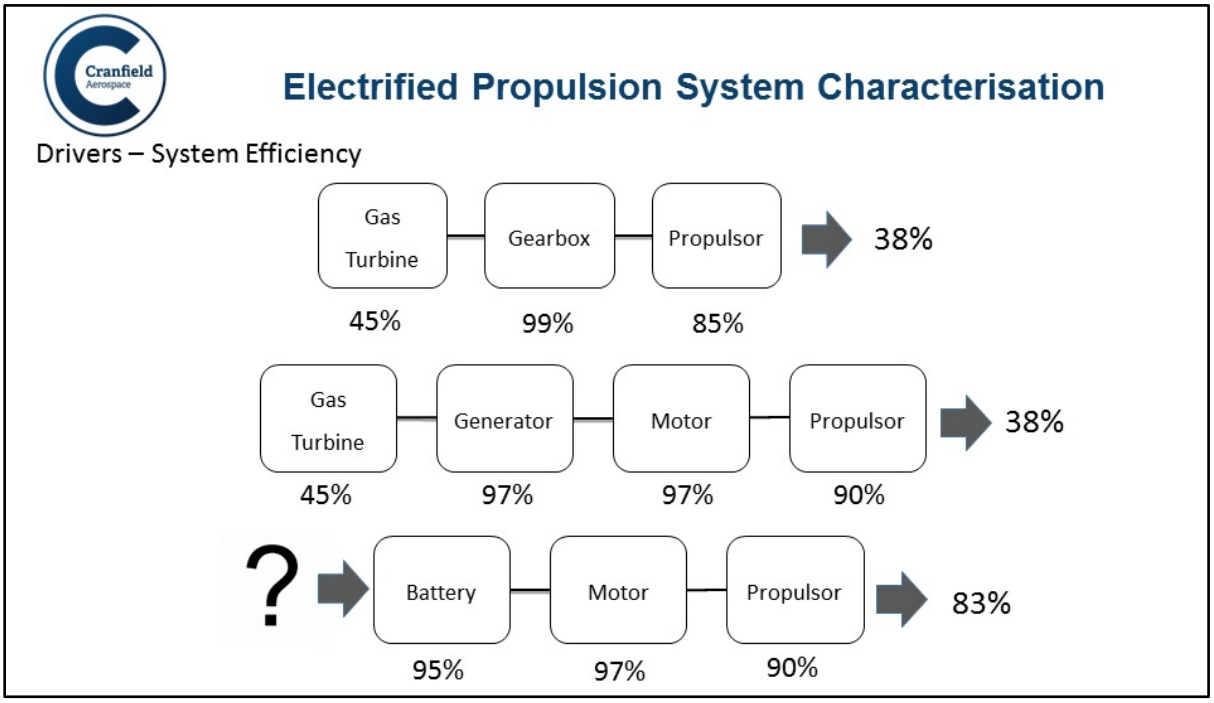
Turbo-Electric & Hybrid Propulsion: from Concept to Operation
Drivers, Metrics and Challenges
Dr Panis Laskaridis, Cranfield University.

This was a presentation that looked into the future. It was an engineer's view of the challenges faced by those who prepare to offer solutions to the demands for a 'greener' environmental footprint that commercial aviation has faced and confronted for many decades. Aircraft that burn gasoline products have used a variety of propulsion units, and manufacturers have been given little option but to accelerate away from a steady improvement in measurable emissions – noxious compounds and noise being top of the list of attributes the industry has addressed. They have achieved a great deal, and simultaneously there has been a steady reduction in the amount of fuel needed per unit of work done throughout civil aviation's century or so history. Even so, everything – from light aircraft to the biggest of airliners - has depended on carrying an oil-based fuel: and as gas turbine engines have come to dominate the scene, so too has kerosene.

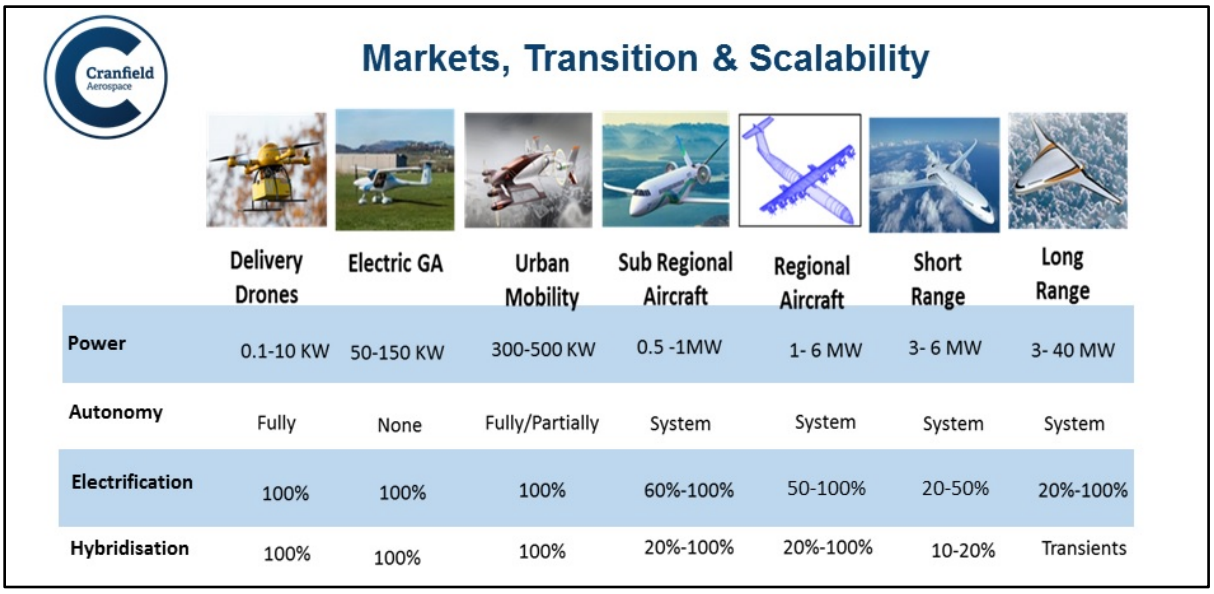


A schematic diagram of the efficiency of propulsion options

This speaker had his eyes focussed on the future and sought solutions. He did not look back in time – the whole presentation was firmly orientated towards answering the question 'where do we go from here?' The essential reminder was that we are at a critical crossroad where there is no desire to regard not changing direction as an option. The only direction that aviation can take, at this point in time, is probably using electric-motivation techniques. The presentation did not dwell on any fanciful science, it kept a wide-viewpoint however, and looked at the scope there is to evolve the best we have with the best we can imagine, and took a very pragmatic approach that allowed the scope to stretch from the smallest to the largest of commercial aircraft in general use and addressed many operational facets.

Commercial operations were categorised into seven sectors: each with a difference of emphasis on the properties of the propulsion system they used. By 'system' he referred to the propulsion unit

(any kind of engine) and the energy source (fuel tanks and/or electrical power storage, e.g.: batteries). He was open-minded to an aircraft being all-electric or based on a combination (hybrid) of liquid fuel and electrical energy storage.



	Delivery Drones	Electric GA	Urban Mobility	Sub Regional Aircraft	Regional Aircraft	Short Range	Long Range
Power	0.1-10 KW	50-150 KW	300-500 KW	0.5 -1MW	1- 6 MW	3- 6 MW	3- 40 MW
Autonomy	Fully	None	Fully/Partially	System	System	System	System
Electrification	100%	100%	100%	60%-100%	50-100%	20-50%	20%-100%
Hybridisation	100%	100%	100%	20%-100%	20%-100%	10-20%	Transients

Summary of the sectors referred to in the presentation

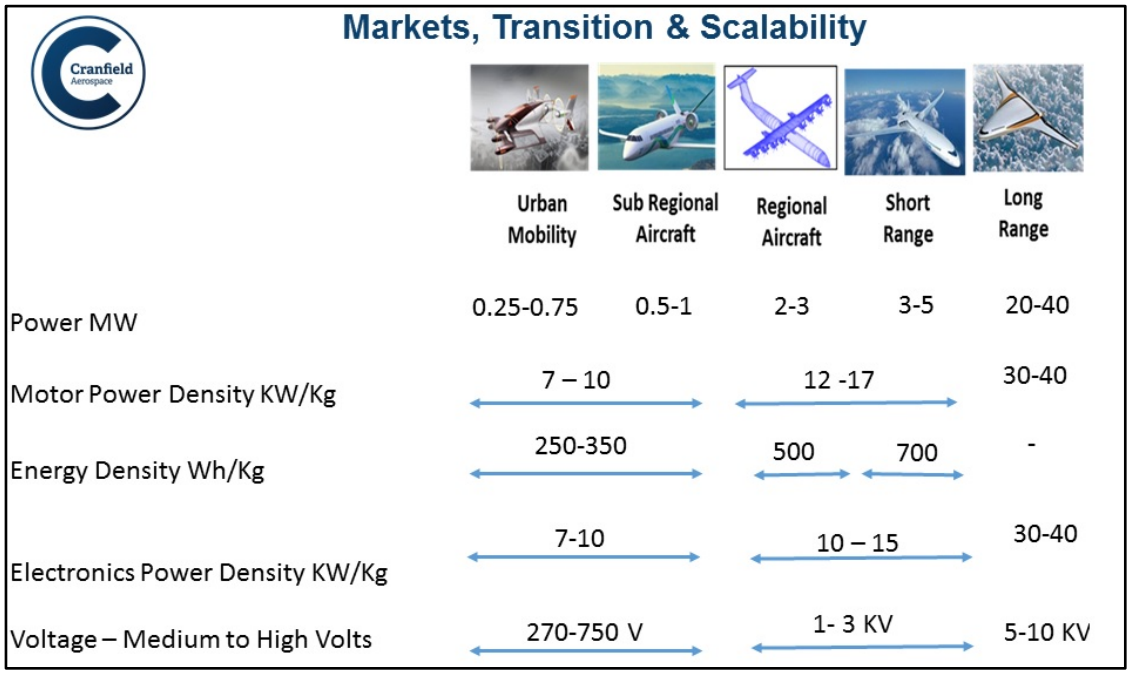
The seven sectors were:

1. Delivery drones – any unmanned and small-capacity vehicle
2. General aviation aircraft – for flight training and private flying
3. Urban aircraft – limited payload aircraft with modest (car-like) passenger capacity
4. Sub regional aircraft – limited payload/range passenger aircraft
5. Regional aircraft – larger capacity with similar/greater range to sub regional
6. Short range aircraft – short-medium range/considerable payload capability
7. Long-range aircraft – aircraft with intercontinental payload/range capability

The presentation used informative charts that provided generic data and highlighted the balance of parameters in categorical rather than specific detail.

There was no inclination to follow those corps that embrace all things non-toxic or less-toxic as saviour elements for humanity. The scene, from current through to future viewpoints, was one seen through more pragmatic eyes. A simple timescale was offered, that might not be precise, but it would be surprising if the order shown was ever to change. He predicted:

Technology	**Feasible first in-service date**
• All-electric	between 2020 and 2025
• Hybrid-electric	between 2025 and 2035
• Turbine-limited hybrid	between 2030 and 2045
• Super-conduction turbine-electric	after 2045 (20xx)



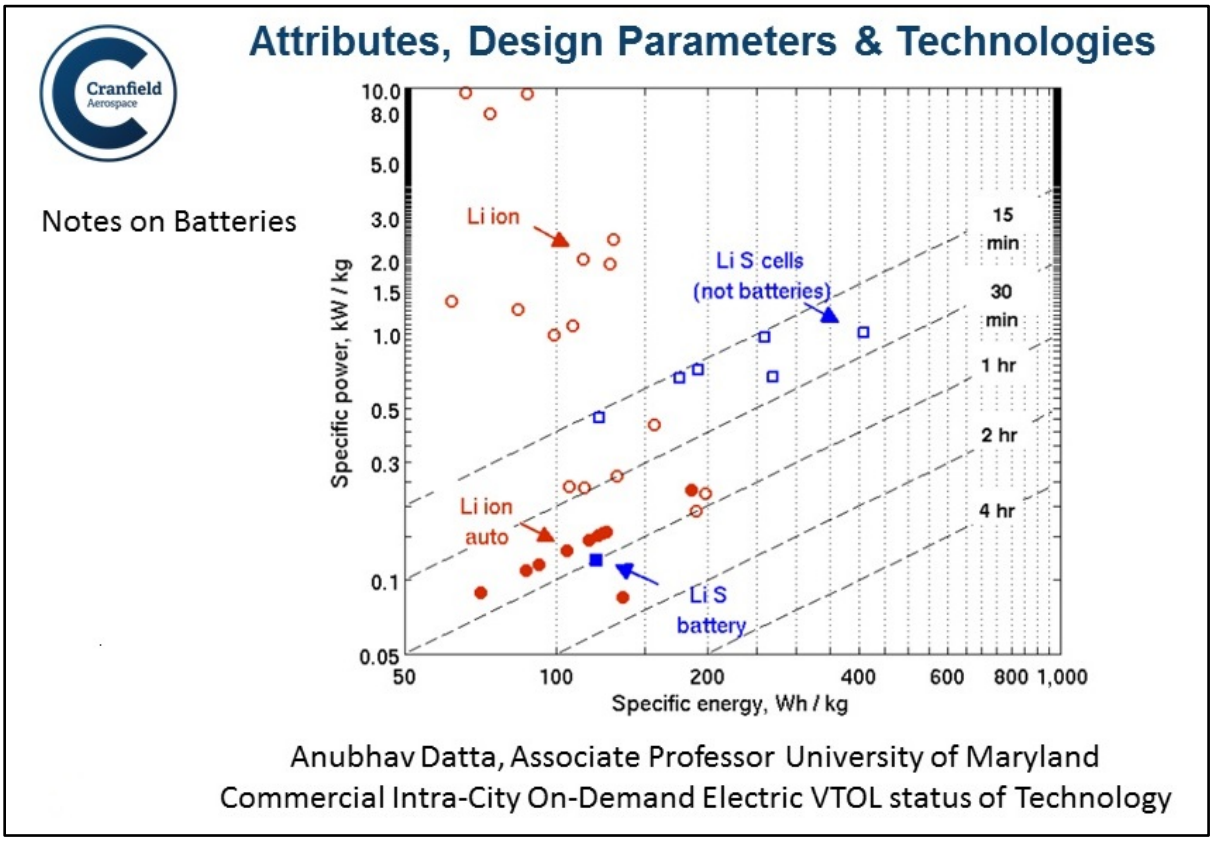
This slide summarises salient attributes of the larger categories

Based on roles, the probable relevance of options was:
- All-electric drones, general aviation and urban aircraft (for surveillance and delivery applications),
- helicopter-related roles (such as remote facility inspections),
- flight training,
- private flying and
- limited capacity 'taxi' (hire and reward) roles which can possibly meet certification requirements within the next decade or so.

The core technologies for these types of operations (relatively short-duration/range and modest payload requirements), are likely to be similar to those already in existence, or with improvements that are already on technology horizons. The presenter did not disregard the likely impact of long-standing safety regulations that might require hybrid propulsion solutions for some roles, but seemed confident that regulators will relieve requirements as evidence of satisfactory capability is gathered from analyses.

Hybrid turbine-electric regional aircraft, largely below 100-seat capacity and with substantial range, but not inter-continental, are expected to be able to cruise with all-electric power, but will need the power of a turbine engine in the more safety critical take-off and landing phases. Emissions and noise impact could be lessened significantly, and the possibility was raised that installations could include boundary-layer ingestion to improve aerodynamic performance and require less power. There was no desire to suggest what aircraft might look like, but there was the enthusiasm to encourage new designer paradigms. The possibility of larger capacity aircraft with similar/greater range was regarded as a likely extension of hybrid technology.

Aircraft with medium/long payload/range capabilities are those that must be the largest and, because they have the most demanding energy requirements, they create the most challenging demands for designers. By proposing that these would be likely to require super-conduction turbine-electric propulsion systems, the presentation suggested that there is little likelihood of seeing an example before 2045.



This slide provided a concise guide to the properties of electrical storage technologies and illustrates the power vs duration trade-off

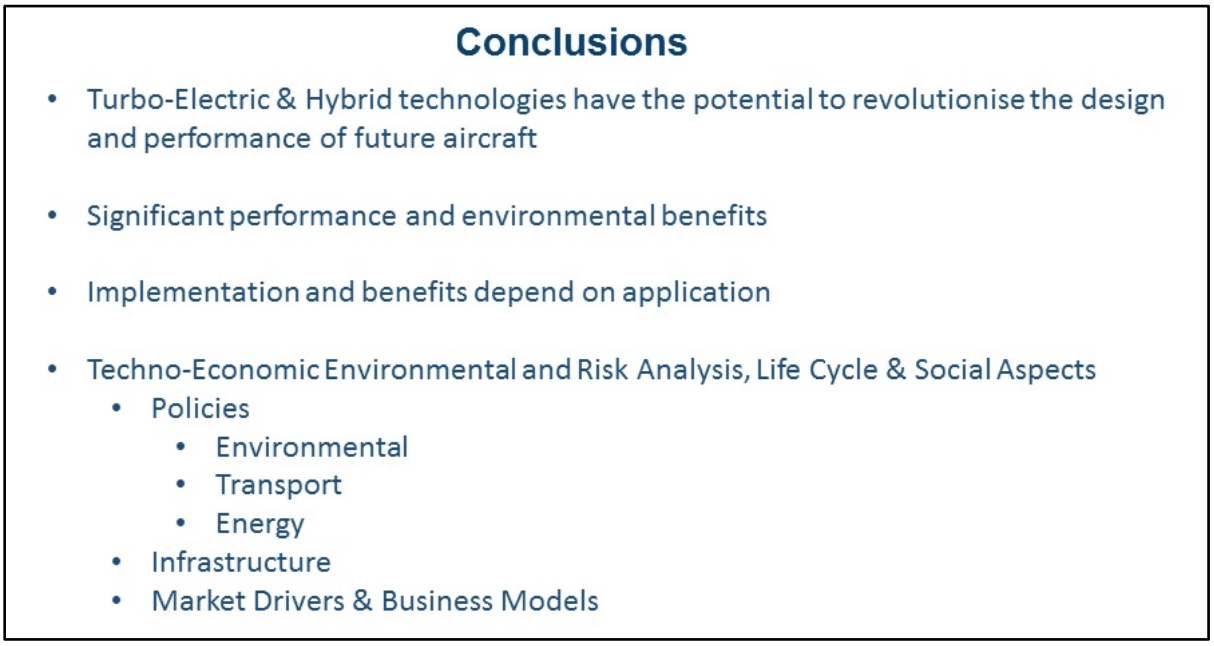
There was the possibility of the much heralded 'all-wing aircraft,' that are intrinsically high lift/drag ratio aircraft. A further potential development cited was of using multiple small propulsion units: these provide redundancy in safety cases and could open the way to having more control over boundary layer flow.

These are aspects so far ahead in time that new opportunities cannot be discounted. At this time these examples are representative of the challenges awaiting the innovative engineers of now, and into the future. A realm is being reached that will require some radical thinking of what is salient, rather than specific, in order to assess the true nature of what balances will be struck between what is established and retained, and what will be new.

This was a thought-provoking lecture, that addressed a broad field of endeavour. The engineer of 1903 could not have envisaged what the aircraft of 50 years later would have looked like: and by which time the jet-age had arrived.

It is probably no easier to make any more sensible extrapolations of aviation as we know it today. In this presentation a sensible road map was provided that fulfilled the promise that it would explore the division between technology and application, and offer an understanding of the various Concepts of Operations (CONOPS) related to hybrid electric technologies, and applied to different aircraft.

Overall, this well-balanced review of existing and emerging parameters fulfilled the promise of outlining "drivers, metrics and challenges." There was considerable technical content that was presented with confidence, in a well-ordered manner, and incorporated balances across the broad picture



The final slide – summary of the issues addressed, or up-coming, in future aviation

of what is on-going, and what is to come. It used descriptions that added detail without resorting to over-simplification.

The audience of about 140 people provided a wide-ranging set of questions, that were answered with clarity, and the general feeling was that this was a very informative guide to what is happening, and what is so often forecast with much aplomb. Attendees commented that they felt well informed to appreciate the new issues likely to change the scene for aviation professionals and passengers in the future.

Lecture notes by Mike Hirst