SUMMARY OF THE EUROPEAN POWER OPTIMISED AIRCRAFT (POA) PROJECT

Dr. Lester Faleiro,
Liebherr-Aerospace Lindenberg GmbH,
PO Box 1363, 88153 Lindenberg, Germany

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Abstract

This paper summarises the results of the European Commission part-funded POA 'Power Optimised Aircraft' project in the direction of the More Electric Aircraft.

1 Civil transport and systems architectures

The state-of-the-art in aircraft systems architectures consists of complex (but well understood and firmly established) technologies which make up the equipment used to power and fly a modern civil aircraft. Here, an Aircraft Equipment System fulfils a major functional aspect of an aircraft and an Architecture is defined as the overall way in which Systems are assembled within the Aircraft.

In a conventional architecture (a basic schematic is shown in Fig 1), fuel is converted into power by the engines. Most of this power is expended as propulsive power (thrust) to propel the aircraft. The remainder is transmitted via, and converted into, four main forms of non-propulsive power.

- Air is bled from the engine high-pressure compressor(s). This pneumatic power is conventionally used to power the Environmental Control System (ECS) and supply hot air for Wing Ice Protection System (WIPS).

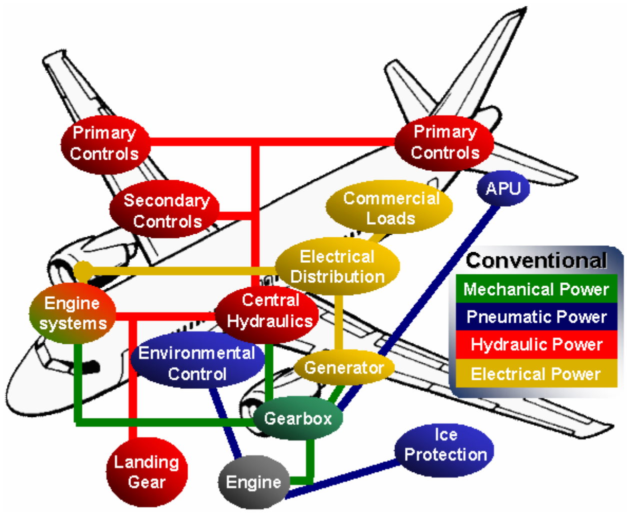

Fig 1: Schematic of conventional power distribution

- A mechanical accessories gearbox transfers mechanical power from the engines to central hydraulic pumps, to local pumps for engine equipment and other mechanically driven subsystems, and to the main electrical generator.
- The central hydraulic pump transfers hydraulic power to the actuation systems for primary and secondary flight control, to landing gear for deployment, retraction and braking, to engine actuation, to thrust reversal systems and to numerous ancillary systems.
- The main generator provides electrical power to the avionics, to cabin and aircraft lighting, to the galleys, and to other commercial loads (entertainment systems, for example).

This conventional distribution of energy is fully reflected in the way aircraft systems are classified and procured today.

2 The POA objectives

Power Optimised Aircraft (POA [1], [2]), which began in January 2002 and will run for 5 years, is the most recent and most integrated research project to address the creation of a more efficient aircraft. As it is widely believed that electrical equipment systems are more efficient that conventional ones, most of POA is based on a vision of a More Electric Aircraft (MEA) for the future. At the *aircraft* level, the project was planned to demonstrate:

- a 25% reduction in peak non-propulsive power usage
- a reduction in average non-propulsive power usage
- a 5% reduction in fuel consumption
- a reduction in equipment weight
- no overall degradation in production costs, maintenance costs or reliability.

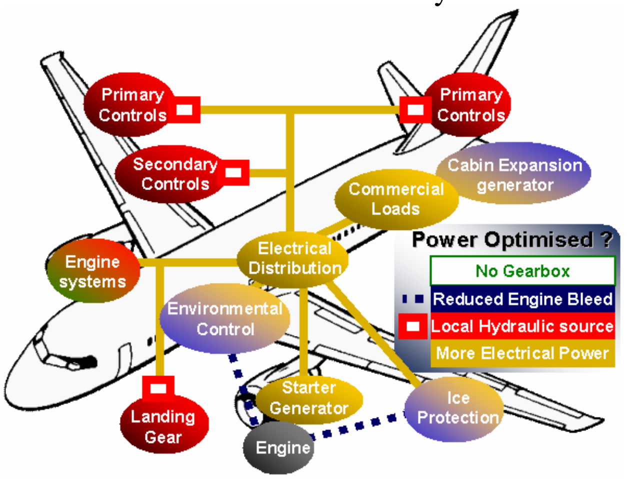

Fig 2: A potential optimised architecture

This was achieved not only through improving individual systems, but also by completely altering the way in which the <u>architecture</u> of aircraft systems is designed (Fig 2). The project is focused on validating the systems that could lead to a 350 passenger twin-engine power optimised aircraft. The remainder of this paper will summarise the outcome of the project, based on the above objectives.

2.1 Reduction in peak power

The main reason for this goal is that 'peak power' tends to size large equipment, and in this case the electrical generation would be especially affected.

In POA, the main peaks occurred during initial climb and final approach (see Fig.3), and were associated with landing gear and secondary flight control system operation. Moving to electrical systems, these peaks were reduced by far more than the expected 25%.

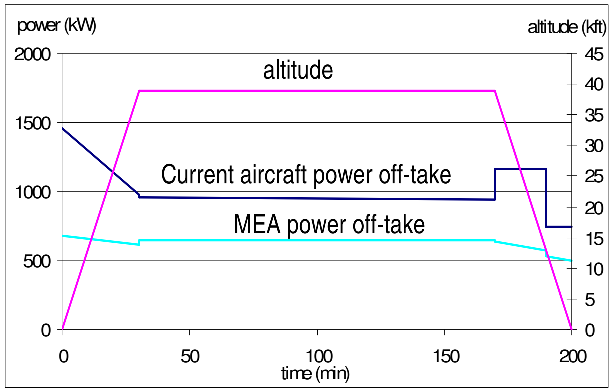

Fig 3: Power reduction during a typical flight

However, it is expected that the flexibility offered by electrical systems can be exploited by the implementation of more 'load management'. By carefully utilising the characteristics of electrical drive systems, for instance allowing generators to overload for a short period of time or temporarily reducing the availability of non-critical systems, peak powers can be flattened out. This will results in generators which are optimally sized for the entire aircraft operation, and not just a few minutes of a long flight.

2.2 Reduction in average power usage

This is the main driver of direct fuel reduction. In POA, using values for the cruise flight, which is the main indication of average power off-take (power being removed from the engine), it was shown that moving to electrical systems can result in:

- 14% less off-take due to the electrification of systems which were driven by accessory gearbox pumps
- 7% less power used by the engine systems
- 14% less power required for environmental control

This gives a total of 35% less power off-take from equipment systems during cruise, with much higher values during climb and descent. Moving to electro-impulse de-icing, for instance, could provide a reduction of 60% in power off-take in icing conditions!

2.3 Reduction in equipment weight

Almost inevitably, the initial results of POA showed that the total aircraft would be heavier than the reference one. Electrical systems tend to be heavier than their conventional equivalents. This is valid for most large systems, but the weight increase is based on conservative estimates relating mainly to heavy power electronics and heavy drive systems, both of which are absent in a conventional aircraft.

New paradigms add to the weight. For instance, the environmental control system (ECS) conventionally receives pressurised air from the engine. The electrical ECS has to generate this pressurised air, adding to system weight.

Nevertheless, there are two reasons to be optimistic. The first is that these results are based on what we understand about electrical drive technologies today. Current research shows that solutions for lighter power electronics and lighter motor drives (the main contributors to higher weight) exist. Implementing what we know about these systems into the POA results gave a result of no net weight increase.

The second reason is that importantly, despite an increase in weight, it was shown that fuel reduction can be reduced (see next section).

2.4 Reduction in fuel consumption

In the end, the ability to apply electrical technologies to the aircraft will be dependent on the reduction in fuel consumption that results from them. This reduction is a combination of many of the above factors, including weight, drag, efficiency, and so on.

The almost surprising result in POA was that despite an increased weight and increased drag (due to the need for the electrical ECS to obtain air from outside), **fuel consumption using electrical systems is better** than that of a conventional aircraft. About 2% reduction could be shown in the project.

This is because electrical systems **tend to be more energy efficient**. As we have seen from the previous examples, this does not necessarily mean that all of these systems are more efficient at the component level. Although in most cases the electrical alternative produces fewer losses, the largest amount of energy saving can be seen in the lack of losses between the energy source and the end user.

This can be seen in an aircraft that no longer needs to waste bleed pressure and temperature, no longer requires restrictors in the hydraulic systems, and no longer requires engine systems to be dependent on engine speed or thrust. This saving can be translated into reduced fuel burn.

In addition, POA has identified that the main savings, in addition to the 2%, is in the flexibility given to the engine to operate differently. The removal of a dependency between systems such as the ECS and the engine provides this new opportunity to improve engine/aircraft integration and operation to provide additional benefits.

2.5 No reduction in production costs, maintenance costs and reliability

An economical assessment was performed, in order to ensure that there is an economic case for the MEA. This assessment was based on the collection of data from every aircraft equipment system involved, and included data on complexity, reliability, direct maintenance costs, aircraft mission, drag changes, aircraft weight and changes to specific fuel consumption of the engine as a direct consequence of the decrease in engine bleed removal and increase in mechanical off-take.

This assessment shows that there is a potential benefit to the airline (the eventual customer for these technologies) from electrical technologies. The assessment also showed that weight is currently a major factor in the results. This shows that future research in the topic of electrical aircraft equipment systems has to concentrate of technologies for reduction of weight in electrical equipment.

3 How equipment systems affect MEA

An important result is that the only comprehensive assessment of how equipment systems should be designed can be obtained when these systems are put together as an aircraft. Some of the lessons learned are as follows:

- **Decreasing engine autonomy**. The engine is no longer the independent power plant that it is usually considered to be. It has to be fully integrated with the aircraft electrical concept.
- **Increasing availability**. The use of four generation sources of electrical power (two in each engine in POA) increases the availability of power to each system with respect to the conventional aircraft. Electrical aircraft may have a higher availability of power than a conventional aircraft.
- **Importance of snowball effects**. The power off-takes at the engine from all the aircraft systems are responsible for 3-5% of the total power produced by the engines (varies by flight phase, engine and aircraft type). To make a substantial contribution to airline operating costs, the systems must be lighter.
- **Effects of Load distribution and management**. The power required from the systems varies considerably depending on which system is active, and in which flight phase it is active.

  A classical allocation of electrical loads could lead to the over-sizing of some generators, which in turn leads to extra weight carried on-board for generating power which is only used for part of the flight. Balancing all the safety and loading requirements in order to make the generators as small and utilised as possible is thus necessary to realise the full potential of the MEA.
- **Power electronics and drives.** These are a major set of components in the MEA. Consolidating these components, either by standardising them, or pursuing further integration, will be one of the future tasks facing an MEA manufacturer and suppliers. The packaging and cooling of electronics, and most significantly their reliability, is playing an ever greater role..

4 Conclusion

The POA assessment has shown that MEA has a real future. Of many architectures examined, including a mixture of conventional and electrical systems, the most electrical architectures showed the most benefits.

Of importance is the initial result that despite a potential increase in the weight of major systems when using current technology, it is possible for an MEA to provide a reduction in fuel usage for a lower operating cost at the aircraft level. In the end, only this result can lead to the launch of such an MEA, or any aircraft for that matter.

However, POA has highlighted that there are some key technologies (to reduce electrical system weight, in particular) to be acquired before a much more electric aircraft becomes commonplace. New research should focus on the validation of such technologies.

5 Acknowledgements

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6 References

[1] Faleiro LF. Power Optimised Aircraft – The Future of Aircraft Systems, *AIAA/ICAS International Air and Space Symposium and Exposition: The Next 100 Years*, Dayton, Ohio. Paper number AIAA 2003-PP10127, 4-17 July 2003.

[2] Faleiro LF. Integrated Equipment Systems for a More Electric Aircraft – hydraulics and pneumatics, 24th *ICAS Congress*, Yokohama, Japan.