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Plastic & Printed Electronics Technology in Aerospace

In this article, Steven Bowns of Technology Futures examines the potential impact of plastic and printed technologies in aerospace electrical and electronic systems.

Few commentators can have failed to notice the great leap in military capability that has been delivered by Unmanned Aerial Vehicles (UAVs) over the last 15 years. UAVs have jumped from effectively large model aircraft curiosities like the British Army's Phoenix in the 1990's to a critical element of military capability today. This capability leap has been achieved partially by a large investment in R&D but also by a multitude of innovations from outside defence. Examples range from ducted fan technology to new electronics technologies that we will examine in this article. Removal of the human pilot has also removed many of the flight safety process constraints, allowing UAV engineers to take greater risks, with consequent greater performance returns. The drive for ever higher levels of endurance, speed, stability and payload in UAVs and the ability to exceed the 7G limit of human endurance has focussed attention on mass and driven the adoption of many weight reduction technologies. This in turn has resulted in widening of the technology gap between military and civil aerospace.

In contrast, over the same period the increasingly complex and burdensome regulatory standards for civil aircraft require that any new technology have a significant and proven track record before it can be adopted. In other words, it must not be new. Accordingly, the civil aerospace sector has been considered by many component and system manufacturers to be slow moving, where quality control and conformance to standards are paramount, with cost and innovation secondary.

Despite this trend, the increases in oil price over the last few years have seen the civil aerospace sector focus again on weight reduction. The cost of aviation fuel has doubled since 2006 and increased almost four fold since 2001. Fuel is typically an airline's single largest operating cost and the increased cost of fuel has bitten hard in to most operators' margins. Fuel efficiency is directly linked to aircraft weight. Roughly, a 1% reduction in aircraft weight equates to a 1% increase in fuel efficiency. This might not seem significant until one considers that for an operator such as the combined BA & Iberia, its 2011 fuel costs will exceed 1 billion Euros. Reducing the weight of its aircraft fleet by 10% would add Euro100M/year to its bottom line. Airline operators are facing fierce commercial pressure and this is being transmitted to the aircraft manufacturers and designers. There is now a degree of immediacy in demands for weight and cost reduction, which coincides with a raft of proven weight reduction technology in the military UAV sector. Due to the long lead times and regulatory constraints of the airframe itself, this pressure is likely to be transmitted onto the component and system manufacturers. It remains to be seen whether they are able to rise to the challenge of transferring and delivering this military UAV technology across to the civil aerospace sector.

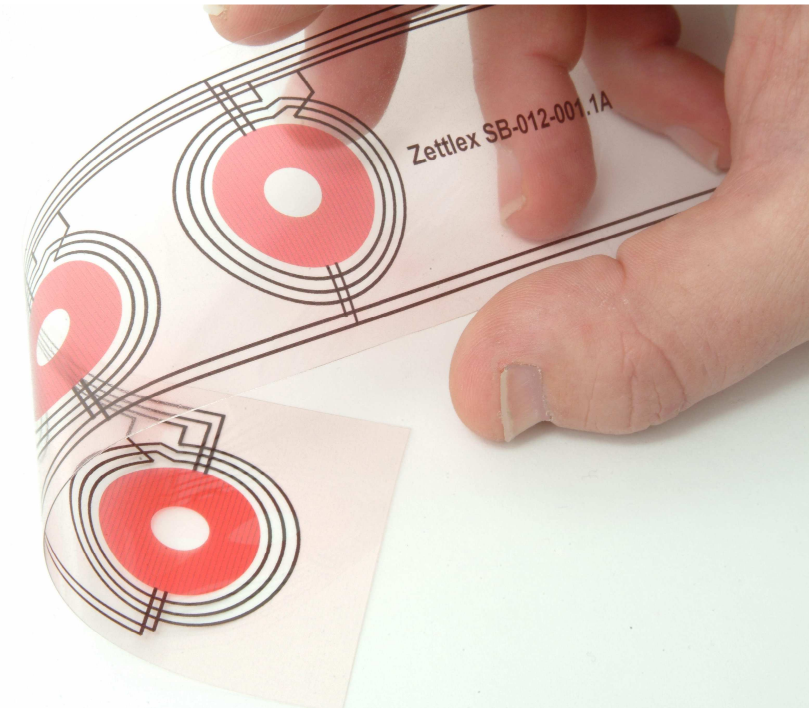
Many of the more obvious candidates for weight reduction – such as airframe and landing gear – have been trimmed to such an extent that there is nothing more to work at. Attention is now turning towards less obvious areas – not least of which is actuation and control systems which can account for up 15% of an aircraft's weight. In a move to meet these new demands, there has been a marked trend away from hydraulically powered actuation and control to electrical power. The use of electromechanical systems as a lightweight alternative to hydraulics was identified as far back as 1979 by NASA. More recently the UK government funded an £11M study called ELGEAR, or Electric Landing Gear Extension and Retraction, for UK industry to develop electrical actuation technology. The transition to electrical actuation and control is still underway for the civil aerospace sector but UAVs in the military sector are already using electrical actuation and control combined with plastic and printed electronics to minimize weight and costs.

Printed electronics technology typically uses conductive, semi-conductive or insulating inks printed on to thin, flexible substrates such as Kapton, polyester or polyimide. The term 'plastic' electronics is also used because many of the substrates are plastic or organic. The technology is most usually associated with high volume applications such as RFID tags, photovoltaic cells and printed circuits for consumer electronics. Until recently, it has not been generally considered for aerospace applications but now that the advantages can be seen so clearly, the technology's range of potential aerospace applications has expanded dramatically.

Printed and plastic electronics technology's most obvious application is as a replacement for cabling. More interestingly, it is also a candidate for high functionality elements such as motor encoders, servo feedback devices and motor control circuits. The technology's extreme lightness and flexibility offers some unusual features and benefits to UAV designers who are able to avoid the cost, weight and mechanical-electrical constraints of traditional cable harnesses, electronic enclosures and connectors. In some instances the flexible electrical laminates may be simply embodied as layers within composite structures. This is already being used by some Formula 1 racing cars.

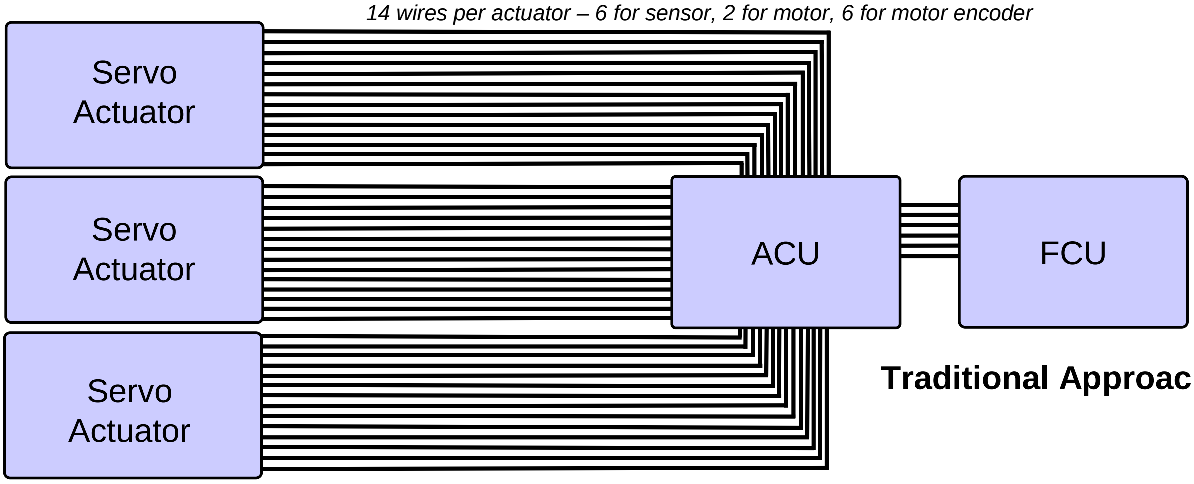
One area where printed electronics is already proving its worth is in sensors and motor control systems for servo actuation and feedback. Such systems are common in flight surface controls, intake ducts, brakes, throttles, undercarriage controls as well as business and first class seating. Traditionally, these systems use an electric motor, motor encoder, gearbox and a transformer based servo feedback device such as a linearly variable differential transformer (LVDT). Whilst such transformer based feedback devices offer precision and reliability they are often as bulky and heavy as the motor. A 300mm stroke LVDT might be a 25mm diameter cylinder, 500mm long and weigh 1Kg whereas its printed alternative is 3mm high, 330mm long and weigh 25 grams. The advantages of the printed approach increase still further when one considers that many aircraft systems require duplex or triplex redundancy. Whereas a duplex or triplex LVDT roughly doubles or triples the original weight and volume, a printed device simply uses more layers of printed tracks to form an isolated second or third electrical system. In a simplex system, the weight reduction is typically >95% whereas in a duplex or triplex system the weight reduction is >99%. On an individual device the net effect is modest, however, when one considers that more than 50 such devices may be used in an aircraft the total effect begins to be very significant.

There is a technology cluster in Cambridge UK, starting from the Cavendish Laboratories in the 1990s, where some of these technologies were developed by companies like Cambridge Display Technologies and Plastic Logic at the turn of the Millennium. They are now being commercialised successfully into printed devices that are in production by companies such as Zettlex in Cambridge (see www.zettlex.com) who produce rotary, linear and 2D sensors as part of printed actuator control systems. Their position and speed sensors are used in fixed and rotary wing military aircraft as well as a raft of other applications in the industrial, medical, oil and gas sectors.

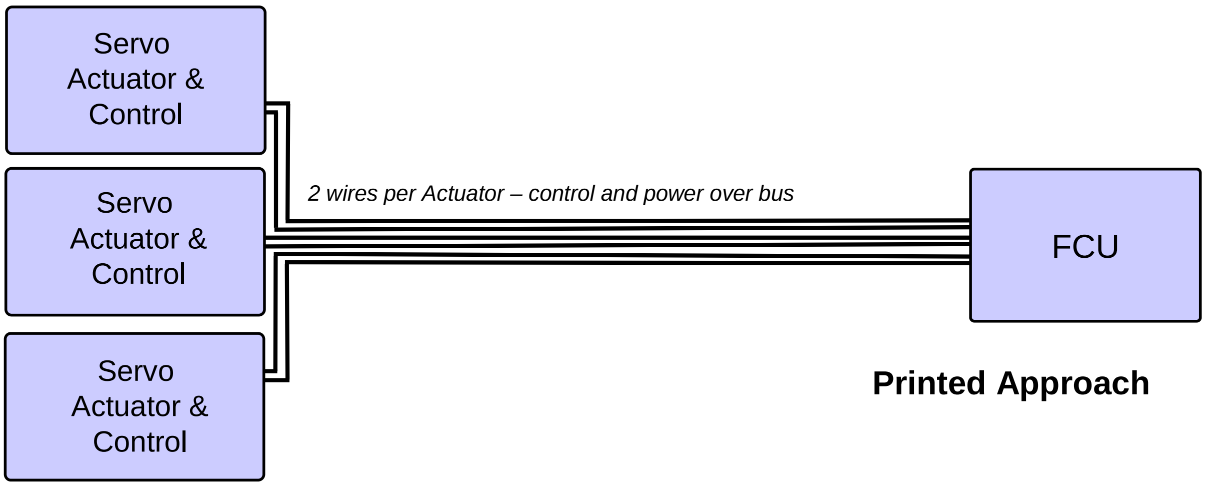


Whilst at first sight such devices might seem flimsy and delicate it should be remembered that the printed forms are rarely used in their 'naked' state. More usually they are fitted by bonding or encapsulation to the host mechanical structures such as the aileron, wing spar, gearbox, seat etc. They will often be completely embedded in resin for example. The printed feedback devices do not need a precision alignment of the moving and stationary parts of the sensors, so further mechanical elements such as guides, bushes, bearing and seals can also be eradicated, producing further weight savings.

The advantages of such printed technologies doesn't just end with weight reduction at the actuator itself. Their weight advantage is increased still further due to the eradication of cabling between actuator and *centralized* control units – typically a flight control unit (FCU) or actuator control unit (ACU). Traditionally, these centralized units receive signals from the servo feedback device and motor encoder and, in turn, transmit the required power to the motor. Such signal and power lines might typically require 14 individual wires per actuator. Compare this to the printed approach where the intelligence is *distributed* to each of the actuators. The modest amount of software for actuation is embedded in to the printed sensor's control circuit. There is no need to transmit power and signals for computation to the centralised unit since the necessary computation is carried out at the actuator itself. Only command signals and power are transmitted from the ACU or FCU to the actuator. Since the command signals can be provided over the power lines only a 2 wires bus is required.



Traditional Approach



Printed Approach

The use of printed electronics technology is already well underway in the military sector – they are flying today on UAVs in their electrical actuation and control systems. In time it will be adopted by the civil sector because its weight and other advantages are so significant over the traditional techniques. The driving force will be increased fuel efficiency as a result of weight reduction. The greater the inflation of fuel price, the greater the pressure for adoption of printed technologies. It is likely that this technology transfer challenge will be laid at the door of component and system manufacturers.

Notes for Editors:

Technology Futures Ltd. is an established technology consulting company based in Cambridge, UK. The company offers clients novel methods in technology strategy, in particular measuring the value of research and technology investments in the defence sector. www.technology-futures.co.uk