T
here are several reasons why a military operator might wish to modernise the avionics systems of its aircraft. These include enhancing mission capabilities, reducing pilot workload, increasing situational awareness, securing compliance with current and emerging regulatory requirements that enable military aircraft to fly in commercial airspace and, of course, avoiding potential obsolescence issues.

Modernising an aircraft’s avionics suite is not without challenges though, particularly if the aircraft was originally manufactured a few decades ago, and it is often necessary to integrate predominantly digital systems – requiring MIL STD 1553 or ARINC 429 buses or newer data protocols (such as Avionics Full Duplex, AFDX, switched Ethernet) – into an aircraft built in the ‘analogue era’. Also, whilst maintenance manuals may exist for these decades old aircraft, detailed information about the avionics systems and how they work may be sparse.

Accordingly, it is necessary to establish a known baseline for the aircraft before you can even begin a modernisation programme. Then you need to understand the customer’s requirements and ensure that they really are what is needed. For instance, a frequent requirement is to add SatComms. How the customer intends to use the system (the concept of operation, or ‘con-op’) will typically dictate which variant of SatComm should be used in light of network coverage and data volume issues.

Armed with the platform baseline and with the customer’s requirements pinned down as tightly as possible, you can then launch into the modernisation programme; following the traditional ‘V-model’ lifecycle for systems engineering, an early phase of which pertains to ‘architecture’, which we will consider from power and signal (data) perspectives.

In most instances, the goal is to add equipment to an aircraft without upgrading its generators and/or power bus bars, which tend to be original fit and costly to replace. Also, most upgrades involve replacing ac powered analogue units with newer, digital ones that require dc power.

An aircraft’s electrical system is a relatively dynamic entity, designed to accommodate different modes of operation, including flight phases, such as take off, cruise and landing. The system must also provide varying degrees of redundancy in the event of losing a generator or key power distribution point. As such, there are many permutations to consider when predicting the effect of adding new electrical loads to the power generation and distribution system. Furthermore, the aviation authorities require proof that any proposed change will not affect safety.

That proof is typically determined through conducting an Electrical Load Analysis (ELA), a steady state and worst case view of all the ac and dc loads summed and compared against the ability of the aircraft’s generation and distribution systems to accommodate the loading.

To date, the most popular way of implementing an ELA has been to use a standard spreadsheet, taking advantage of its ability to perform calculations. However, it has always been necessary to apply a variety of rules to validate the legitimacy of some of the figures being entered. For example, power factors can never be more than 1.0 and duty cycles cannot exceed 100%. Because of the complexity of an aircraft’s electrical system, the spreadsheet soon becomes cumbersome and you start spending a disproportionate amount of time verifying that the spreadsheet is doing its job properly.

Frustrated by the lack of a more suitable tool for performing ELAs, and in light of how many avionics modernisation programmes it performs, Marshall Aerospace and Defence Group devised its own tool, called SERIES (System Electrical Rating Integration Evaluation Software), for performing ELAs.

When developing the tool, the company started by modelling the connectivity that exists in a Hercules C-130’s electrical distribution system, a platform on which it undertakes much work. Next, certain bus elements, including generators, transformer rectifier units, inverters and batteries, were modelled, as well as a variety of loads (anything from a light bulb to a galley oven). It was also necessary to reflect that many loads have multiple modes of operation and therefore...
varying power requirements.

Accordingly, Marshall can now run a range of ‘what if?’ scenarios to evaluate the impact of an avionics upgrade (or even making minor changes to the avionics suite) with drag and drop ease. The company can also model the failure of any given generator or bus element in order to observe the ramifications on the electrical system as a whole.

An avionics modernisation programme typically requires integrating systems that were designed decades apart. For example, two H-model C-130 Hercules aircraft, originally built in the 1970s, and two stretch variants built in the 1990s, recently underwent extensive avionics modifications in Cambridge.

At the heart of the programme was the installation of a Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM) compliant Flight Management System (FMS) and display and surveillance systems. The display system consists of six flat panel displays which incorporate the functionality of the many original electromechanical displays and the surveillance systems, including Enhanced Traffic Alert and Collision Avoidance System (ETCAS – which is mandatory for aircraft entering controlled airspace) and an Enhanced Ground Proximity Warning System.

However, the original analogue autopilot systems for each aircraft had to remain, which meant employing signal converters so old and new could interface. At a fundamental level, signal converters are d/a and a/d converter circuits, with the appropriate algorithms and signal conditioning to ensure the signals from/to the converter comply with the buses on which they reside.

The autopilot required 13 analogue I/O signals whereas, on the digital side of the converter, the inputs from the FMS and displays operate over an ARINC 429 data bus. With the luxury of having the aircraft on site, the company reverse engineered the autopilot’s communications protocols and then devised suitable conversion algorithms. Additionally the COTS ARINC 429 to RS-232 and ARINC 429 to MIL STD 1553 converters were programmed to support specific system integration.

With reuse in mind, the converters were built to support other ‘translations’, including ARINC 429 to RS-232 and STANAG formats.

In summary, when upgrading the avionics suite of a platform that might be a few decades old, systems integration lacks the ‘plug and play’ ease that exists elsewhere in the electronics industry. Also, interfacing equipment frequently requires reverse engineering communications protocols and developing custom signal converters which, along with the overall system, require substantiation before they can be certified for flight.

As for SERIES, though it was developed to meet Marshall’s in-house requirements for a Hercules C-130s avionics upgrade programme, the software is currently being updated to enable the modelling of any power architecture. Once done, the software may be commercialised.

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