By Mark Robins

AVIATION WIRING, CONNECTORS AND INTERCONNECTS

TYING EVERYTHING TOGETHER BY HELPING ELECTRICAL AND ELECTRONIC SYSTEMS COMMUNICATE AMONG DIFFERENT DEVICES.

Aviation wiring, connectors and interconnects seamlessly transmit power and data to connect electronic and mechanical systems, including everything up to mission-critical systems and flight controls. These components form an electrical wiring interconnect system (EWIS) rather than a conglomeration or assembly of individual components. This system can be likened to an aircraft's central nervous system — making sure the correct information is received at the right place at the right time.

Jeff Behlendorf, director of product management at Amphenol-CIT, Franklin, Wis., says it's the wiring that ties diverse aircraft systems together. "That wiring comes in a wide range of forms specifically designed for aviation use and tested to assure reliability, safety and signal integrity."

Wiring is selected and sized to transmit power or data while maintaining safe operating conditions (below maximum rated temperature, operate within verified voltage limits, etc.) and minimizing signal loss. Chris Wollbrink, engineer at Lectromec, Chantilly, Va., explains that wiring serves a similar purpose to the central nervous system (signal wires) and cardiovascular system (power transmission). "Signal wires transmit data and tell operators and equipment about the aircraft condition, while power transmission wires respond to inputs from the pilots and computers. This is analogous to our nervous systems communicating with our brains and our muscles responding to stimulus or commands."

Lectromec's Chris Wollbrink compares aircraft wiring to the central nervous system (signal wires) and cardiovascular system (power transmission) of humans. Lectromec image.

Connectors provide an interface between the wiring and the system components, such as fans, relays, actuators, computers, radios and displays. "Connectors are generally designed to be connected and disconnected easily to allow service and replacement of these system components. Interconnects often provide a similar function, but are often semi-permanent connections and not designed for regular disconnection," Behlendorf says. Connectors and interconnects can even provide environmental protection from moisture and aviation fluids.

Wollbrink says connectors and interconnects serve as terminations in the wiring to maintain harnesses and minimize the amount of wiring that must be replaced during inspections. "Connectors are enclosed devices that serve to protect pins from the environment and unwanted pin contact. Interconnects are a more general overarching term, of which connectors are a part of. Interconnects include, but are not limited to, terminal blocks, bus bars, and structure bonding."

Maintaining and Repairing

Maintenance and repair of aircraft wiring and associated components require skilled technicians and the right tools. But Christopher Ericksen, global product specialist at W. L. Gore & Associates, Inc. Newark, Del., says the first line of defense is a good offense, meaning that products "should be designed with potential failure modes in mind and preventative features such that the need for maintenance or repair is minimized or eliminated altogether. If it cannot be designed in, due to various other requirements (including weight), then the next option would be to train installers and maintainers in best practices. For repairing, designing systems with field-replaceable components or sacrificial components in areas that are most susceptible to damage. Service

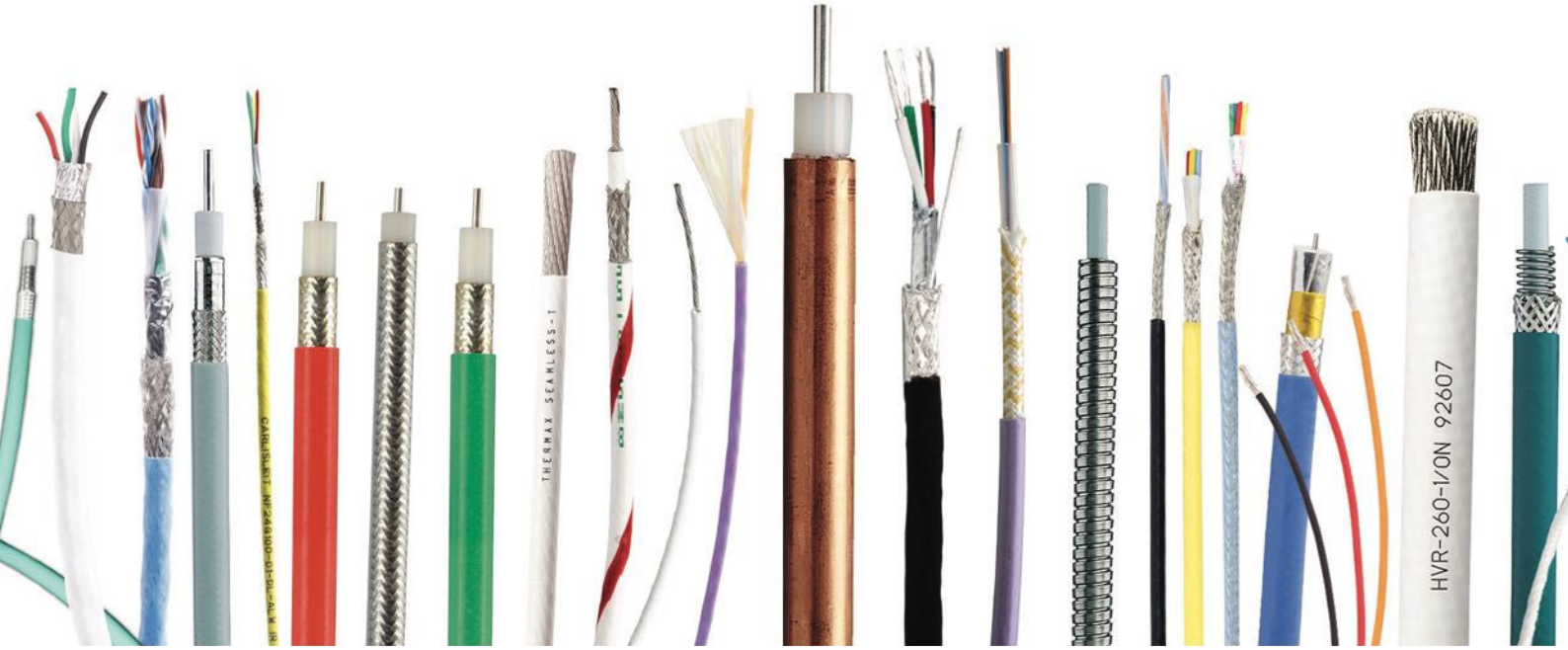
loops can be used to make sure there is additional length in order to re-terminate connectors onto the cable."

For wiring and connectors/interconnects acting as one solution or a cable assembly, maintenance usually means removing the assembly from the aircraft when end of life is reached and replacing it with a new assembly. However, if field repair is necessary, certain manufacturing techniques for cable assemblies like wiring service loops and signal/wiring redundancy can be applied to the connectors/interconnects.

For example, Matthew McAlonis, engineering fellow, Aerospace TE Connectivity, Berwyn, Pa., explains a wire service loop adds extra length at the rear of the connectors. "If the connector's contacts are damaged and need re-termination, the wire service loop's extra length will accommodate this repair while also allowing the cable assembly's intended overall length to be maintained. Another example is if the connector is connected and disconnected at a high cycle rate (500 cycles), wear and tear on connector threads and contacts can occur. To overcome this, a connector saver can be used. Connector savers are easy to replace and save on the cost of rework."

Shown here are Gore's wires, cables, and cable assemblies for aerospace applications. W. L. Gore image.

To repair connectors, often they have to be disassembled, pins extracted and terminations replaced to troubleshoot wiring problems. Most aircraft wiring uses crimp termination methods, which can be done with hand tools and the correct dies to match the contacts.



Amphenol makes a variety of aviation wires as shown here. Knowing the right tools for the connectors and wires you are maintaining will make the job much easier and the finished work more trouble free, says Jeff Behlendorf, director of product management at Amphenol-CIT.

"Some specialized terminations, such as Ethernet cables, require careful attention to make sure the wire twist is preserved and the relative wire lengths are consistent between pairs," Behlendorf says. "Coaxial cables for antennas on the aircraft have complex multi-layer strip requirements, which may be assisted by specialized stripping equipment to assure no damage to the wiring when removing jackets and shields. Be sure to know what the right tools are for the connectors and wires you are maintaining and the job will be much easier and the finished work more trouble free."

For part 25 aircraft, all EWIS components are subject to regular inspection. At the OEM level, Wollbrink believes the best solution for maintaining EWIS is by designing a system with high accessibility and that accessibility coupled with selecting the correct EWIS components for the application are critical. "To minimize the aircraft downtime to service EWIS components, accelerated aging techniques can be used to determine the reliable service life of candidate components; these aging tests generate data to determine how well the components will fare in the harsh environments that EWIS components experience. Basic electrical thresholds must be maintained based on specifications and standards as well."

Wollbrink adds that for maintainers, repairing the EWIS following accepted industry guidance, such as ASTM F2799 and/or the manufacturer's guidance is the best approach. "For inspection, guidance from FAA AC 25.27A and MIL-HDBK-522 provide a great basis for what should be caught during routine inspections."

EWIS Special Factors

A complete aviation solution should have robust wiring, connectors and interconnects that can withstand harsh and hostile high-altitude operating environments. Additionally, the end application can drive specific requirements for performance at demanding high/low temperatures, mechanical strength in high-vibration environments, meet military specifications, etc. Materials and constructions are selected and tested to make sure wire connections remain reliable even as parts freeze, thaw, bake, expand, contract and shake during a flight. "Commercial aircraft require flight controls with the most rugged and durable connectors to perform within extreme temperature fluctuations of +50°C while on a hot tarmac to –60°C while at in-flight altitudes,"

TE Connectivity says they are focused on reliability, durability and sustainability. TE Connectivity image.

says can bu. "Components must also withstand repetitive high use in commercial applications."

Vibration, chemical exposure, salt fog, sand/dust/dirt contaminates and other factors are well documented in the MIL-STD-81490 for Airframe Cabling. FAA regulation 25.1703 dictates wiring, connectors and interconnects shall be qualified to the installation environment and must operate appropriately in that environment. However, Wollbrink explains with the advent of EVTOLs, which, right now, do not fall under part 25 regulations, definitions have become problematic. "The current generation of EVTOLs operate at higher voltages (currently between 600-1000 Volts), which has been a topic of much discussion among the certification authorities and standards organizations."

Reduced Size and Weight

Aviation parts manufacturers are always looking to find ways to make their solutions lighter and smaller. Material set selection is critical to reducing the size and weight of interconnects while not sacrificing electrical or mechanical integrity and robustness.

For example, Grant Lawton, application engineer at W. L. Gore & Associates, Inc., says that by choosing an optimized insulative material one can decrease conductor size without compromising

HEICO

HEICO designs, manufactures, and distributes wiring harnesses, connectors, cables, and other interconnect-related components for niche uses, such as high-voltage, high-current, mil-spec and commercial aerospace, and various rugged environments.

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Shown here is TE Connectivity's CeeLok FAS-T Connector. TE Connectivity image.

performance. "When down-gauging conductors, special attention must be paid to mechanical strength and performance over temperature. Robust testing and qualification are important to evaluate that performance has not been compromised as we reduce size and weight. High-strength material sets have driven size and weight decreases while meeting or exceeding aerospace industry requirements. System driven increases in bandwidth and frequency range have driven the need for higher performance interconnects that not only must function 'out of the box', but after installation, and over time."

Wollbrink says a common change that he has witnessed is the incorporation of aluminum conductors and smaller connectors. "These components must undergo much of the same testing as existing components to ensure that they will be able to handle the environments that they will be installed in. Aluminum conductors have become more prevalent in aircraft despite their lower conductance and malleability when compared to copper. Techniques to increase flexibility via smaller strand thickness and braiding techniques have allowed aluminum conductors to be more resilient and competitive to their copper counterparts."

Carbon-nano tubes have made significant progress in the last decade, which could contribute to saving weight as well. Wollbrink notes that carbon nanotubes will need further testing to become applicable for high performance electrical cables but will reduce the weight currently occupied by copper and aluminum.

EWIS Evolution

High data and power management has created EWIS needs. Modern aircraft use five times as much electrical power as it did just a few decades ago. McAlonis says that makes power switching systems with embedded sensors and electrical monitoring equipment more vital than ever to improve efficiency and load balancing. "Fiber optics and nano miniature connectors in navigation and communication systems also allow faster data transfer."

The industry has continued to push for higher data rates, higher voltages and higher operating temperatures as aircraft manufacturers increase the sophistication and performance of their new aircraft designs. Behlendorf says this has created "material innovations like composite connector bodies, ceramic insulators, electroplated polymer shields and a wide range of advanced flouropolymers used in components. Environmental regulation has also driven some innovation, evolving fire retardants, platings and base metals used in components."

Improved EWIS Signal Integrity

Signal integrity has continued to improve having received increased attention through enhanced performance requirements. Patrick Jemmi, application engineer at W. L. Gore & Associates, Inc., believes "The more we test, the more we learn and improve. The prevalence of sensors, increased data rates/frequencies, and overall information has empowered AI decision-making capabilities. That data flows through the interconnects. Maintaining the interconnect signal integrity is critical to AI making the correct decisions. Typical electrical parameters such as power, loss, shielding effectiveness, crosstalk, and phase matching/tracking all contribute and are important to evaluate. Fiber optics can help system performance, versus copper, by minimizing loss, eliminating shielding effectiveness concerns, and having extensive bandwidth while significantly reducing size and weight."

Because EWIS quality and reliability is so critically important to flight system management, Behlendorf believes the industry has tightened manufacturing tolerances to achieve higher data rates in the challenging aircraft environment. "This includes adapting fiber optic technology to the aviation market as well. Aviation fiber is very different from telecom fiber and uses a unique jacketing and termination system in order to tolerate the changing temperatures, pressures and vibration on board an aircraft."

In addition to its smaller size, signal integrity and weight advantages, fiber is inherently immune to EMI and crosstalk issues, has massive bandwidth over significant distance compared to copper, and typically weighs much less. Cables are typically smaller because they do not need the electrical shield layers that add to both weight and cable diameter.

High Voltage

More Electric Aircraft (MEA) and All Electric Aircraft (AEA) have created new application opportunities for high voltage power and electrical distribution systems. There are many potential benefits of high voltage power, but the opportunity carries with it safety concerns. The wire/cable insulation should be selected that can withstand the system's high voltage for the entire vehicle life, even when considering the long term electrical and environmental stresses. Further, the installation must undergo greater scrutiny to ensure the separation distances from critical systems and/or structure are maintained throughout the vehicle.
Chris Wollbrink, engineer at Lectromec, Chantilly, Va.