New Technologies Tackle UAV Challenges

(Photo: U.S. Army)

Unmanned vehicles for air, land, and water represent an increasingly-important capability for virtually all military services worldwide. Because each new generation of device technology promises capabilities and higher levels of overall performance for unmanned vehicles of all types, military customers expect these benefits in the latest UAV offerings. To meet these expectations, systems engineers must deal with increasingly difficult problems of thermal management, power budgeting, EMI emissions and susceptibility, weight, size, cabling, connectors, antenna management, and command/control functions. Several new technologies and innovative packaging concepts now provide better solutions to these issues.

Thermal Management Solutions

Since unmanned vehicles have no requirements for human occupants, SWaP penalties for life-support systems and crew or pilot quarters are eliminated. The downside for system designers is that UAVs are therefore expected to operate over temperatures ranging from -50°C to +75°C. Often unappreciated is the fact that these limits can be more difficult to meet when the vehicle is on the ground and powered down for sustained periods of time between missions. Primary design concerns here are non-operational effects of mechanical stress and packaging integrity. These are usually well documented as storage temperature specifications, which can help predict survivability on mid-winter airstrips in Alaska and mid-summer runways in the mid-East.

There are numerous operational temperature issues. If the unit is not provided with a standby heating system, starting up from -50°C often requires a warm-up delay and the use of heaters or partially powering up some equipment to heat the more temperature-sensitive equipment. Notorious for problems at low temperatures are crystal oscillators, batteries, capacitors, and some semiconductor devices like A/D converters.

At high start-up temperatures, similar care must be taken to cool down the equipment before applying full power. Otherwise, components like processors and FPGAs can sustain permanent damage, completely disabling critical subsystems within the vehicle. Cooling strategies must transfer heat to a heat exchanger coupled to the outside surface of the vehicle or to outside air. Methods of moving the heat include heat pipes, carbon nanotubes, circulating air or liquid, refrigerators, thermionic coolers, and some promising new nano-technology cooling engines.

Once the UAV is operational, these same structures can continue to regulate internal temperatures, often consuming relatively little energy because of self-heating of the payload systems and the normally cold skin temperature of the vehicle once it reaches operational altitude.

Often a simple, independent vehicle thermal management processor capable of operating across the entire temperature range controls the heating and cooling systems and initiates operational power to the UAV systems when ready.

Open Packaging Standards

Even though each UAV targets a specific class of applications and missions, systems designers can reap significant benefits by exploiting the latest open standards for the many internal sub-systems. An outstanding example is the VITA OpenVPX standard, now also adopted by ANSI. It defines numerous mechanical and electrical profiles for circuit boards, backplanes, chassis, connectors, as well as cooling and power distribution methods, all capable of withstanding severe military environmental conditions.

Particularly appropriate for UAVs are the numerous cooling methods for OpenVPX defined in the VITA 48 standard, which includes conduction, liquid flow-through, air flow-through, air flow-by, and variants. Designers can select the most appropriate cooling technique for a given UAV by surveying vendors for availability of VPX solutions sharing a common VITA 48 cooling method. This can greatly simplify the overall thermal design of the vehicle.

Another important benefit of open standards is improved life cycle support, especially for military programs looking for multi-year acquisition and installation phases, followed by ten or more years of operational life, that can be fully supported with maintenance and repairs. Obsolescence of critical components like memories, processors, or FPGAs is all too common and quite difficult to predict. In some cases, redesign of modules or sub-systems is the only solution, and compliance with a well-defined standard helps ensure success.

Upgrades become far easier when an older module can be replaced with a new one that exploits the latest technology and delivers new performance levels, but yet still complies with the OpenVPX infrastructure to minimize system integration efforts.

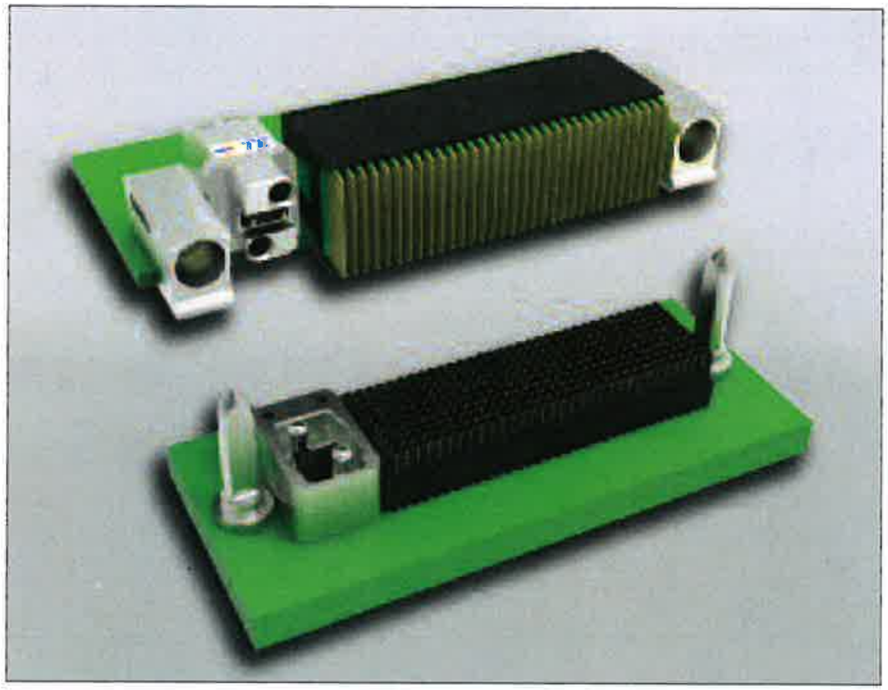

Figure 1. VITA 66 optical connector blocks for a 3U VPX module (top) and backplane (bottom) are installed in place of electrical RT connectors (black). Each holds an MT ferrule with 24 fiber cables. (Courtesy: TE Connectivity Ltd.)

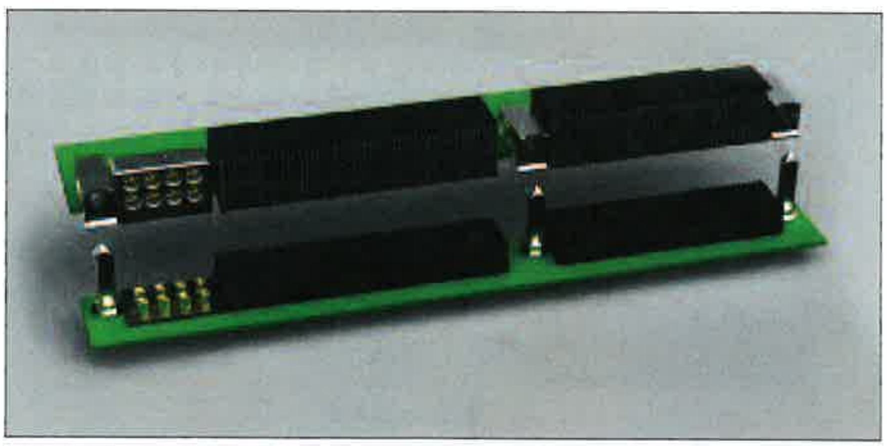

Figure 2. VITA 67 RF connector blocks for a 6U VPX module (top) and backplane (bottom) are installed in place of electrical RT connectors (black), and support eight coaxial connectors. (Courtesy: TE Connectivity Ltd.)

Making Good Connections

A peek inside a military UAV reveals a staggering array of wires, cables, harnesses, and connectors, accounting for a significant share of vehicle weight, and having a major impact on both operational costs and mission endurance.

Because UAVs are loaded with sensors, antennas, processors, cameras, telemetry systems, radios, radars, navigation systems, jammers, power supplies and cooling systems, the necessary interconnects are often highly specialized to match the link.

Some new power systems distribute higher voltages using smaller diameter wires to minimize weight. Many new classes of POL (point-of-load) switching regulators drop the nominal 24 or 48 VDC distribution bus to lower local voltages required for each subsystem, while maintaining high efficiency across a wide range of supply voltages and load currents. More complex devices can maintain regulation across high pulse current loads to support radar and countermeasure equipment.

Parallel digital lines for high-speed data connections are being replaced by gigabit serial links at virtually every level of embedded systems. The benefits are fewer wires, smaller space, and higher rates. Within board-level products, gigabit serial links join processors, FPGAs, data converters, network interfaces, and storage interfaces. Within a chassis, these same serial links stretch across the backplane for connecting boards and for bringing I/O signals to bulkhead connectors. UAV subsystems are now exploiting these serial links to replace fat, parallel data cables to save space and weight. Two of the most popular gigabit proto-

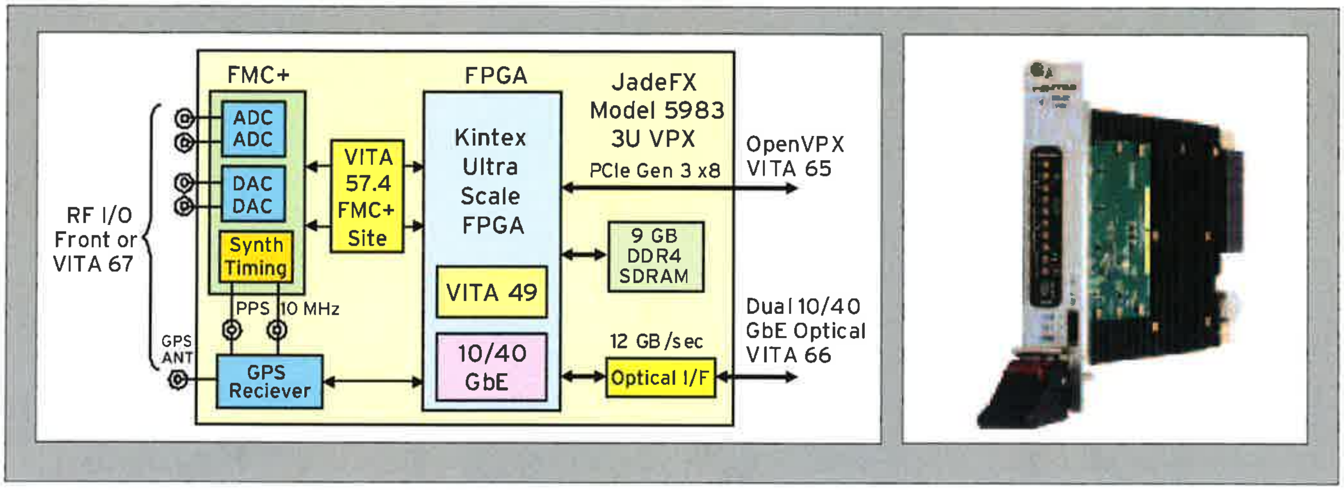

Figure 3. Pentek Model 5983 3U OpenVPX Kintex UltraScale FMC+ Carrier supports numerous VITA standards for new DoD initiatives for software radio embedded systems. (Courtesy: Pentek, Inc.)

cols in UAVs are PCIe and Ethernet at speeds of 1, 10, and 40 GB/sec.

Switching to Light

A major trend for high-capacity data links is replacing copper cables with optical cables that offer many compelling benefits.

Optical cables are completely free from EMI (electromagnetic interference) emissions. This not only eliminates unwanted radiation that can induce signals in other cables and sensitive equipment, it also prevents unauthorized interception of sensitive information by cable "sniffers". The same trait makes optical cables immune to interference and contamination from generators, antennas, and other noise sources.

Optical cables also offer less weight; smaller diameter; lower cost per foot; immunity to water, salt, and corrosion; as well as greater tensile strength. Connectors do require care in cleaning, installation, and handling, but once installed, are quite reliable.

All these benefits of optical cables are vitally important to UAVs, where many different sub-systems, sensors, and antennas are crowded together in very close proximity.

Over the course of several years, the VITA 66 group has spawned several variations of optical interfaces between VPX modules and backplanes. The most recent ones use industry-standard MT ferrules, each typically containing 12 or 24 optical fibers. Metal housings on the modules and backplane replace the electrical RT connectors, and provide precision engagement and spring-loading of the mating MT ferrules for reliably aligning the polished ends of each fiber when the module is inserted. (Figure 1)

Several component vendors are offering new compact, power-efficient optical/copper interface devices directly compatible with the gigabit serial ports on FPGAs and processors. Their products are competing for design wins for VITA 66 systems, which helps advance performance levels and lower costs.

Taming RF Signals

RF signals to and from antennas traditionally require bulky coaxial cables not only to minimize signal loss, but also to protect against interference when passing near and between power generators, switching power regulators, and transmit antennas.

New major U.S. DoD initiatives like SOSA (Sensor Open System Architecture), MORA (Modular Open RF Architecture), and CMOSS (C4ISR/EW Modular Open Suite of Standards) share a common goal of digitizing RF and IF signals as close to the antenna as possible, and then delivering digital streams via gigabit serial network links. The same applies to transmit signals, which are sent as digital streams to transmitters, where they are converted to analog, power amplified, and delivered to the local antenna. And, tracking the migration to optical, these standards call for optical interfaces for the high speed links.

This new architecture brings many benefits. RF circuitry, amplifiers, data converters, FPGAs, and network interfaces can all be incorporated within compact sub-systems directly behind the antennas. These "radio heads" are connected via network switches to the appropriate equipment, neatly eliminating coaxial cables and RF switches, and traditionally hard-wired sources and destinations.

Not surprisingly, these new DoD initiatives incorporate OpenVPX as the hardware platform, capturing the many benefits listed earlier. To facilitate designs of radio heads, VITA 67 standards define several generations of RF backplane interfaces to simplify system integration. Mating metal housings on the modules and the backplane contain multiple coaxial connectors that are installed in place of some of the VPX electrical RT connectors. This eliminates the need for front panel coaxial cables, which greatly complicate service and maintenance operations.

Some of the earlier VITA 67 standards supported four or eight connections, as shown in Figure 2. But the new smaller Nano RF connector variants now under discussion provide up to 26 coaxial connections, which help support phased-array antennas that require one RF signal for each element. These electronically-steered arrays are particularly well suited for UAV radar and EW systems, where mechanical steering is often impractical.

Observing Protocol

With so many diverse sub-systems within the typical UAV, orchestrating them to conduct a coordinated mission is a daunting task. One major initiative is the new VITA 49.2 Radio Transport Protocol approved within the last year. It defines standardized methods for delivering control, status, and payload data for digital software radio subsystems so that information streams to and from different types of radios, radars, EW, and SIGINT systems share common formats.

This allows signals acquired by one radio head to be delivered across switched optical networks to one or more consumers, so signals can be shared for different purposes. VITA 49 adds one more degree of consistency, not only between vendors, but also for upgrades and maintenance.

Figure 3 shows a recently announced 3U VPX software radio module trageting the new DoD architectures like SOSA and MORA. Front end data converters operating at 3 GS/sec capture and generate wideband analog RF signals, matching requirements for emerging radar, EW and communications bandwidths required for advanced UAV sub-systems. It also incorporates 10 or 40 GbE interfaces to transfer VITA 49 digital IF/RF signals across VITA 66 optical backplane links to an OpenVPX signal processing system.

Looking Forward

The expanding role of UAVs in military operations, coupled with the rapid evolution of new device technology ensures a vigorous pursuit of extending UAV capabilities and performance levels to meet new requirements. It is clear that open standards are becoming increasingly important, not only to help integrate these new technologies, but also to help secure customer adoption of next generation vehicles.

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