

# Military

## EMBEDDED SYSTEMS

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INCLUDING:

## Direct spray enclosures offer flexible electronics deployment on airborne platforms

By Andy Finch



Photo courtesy of Northrop Grumman

*Vehicle integrators are challenged to provide enhanced processing capabilities in unpressurized space on airborne platforms. Direct spray enclosures offer an alternative approach to environmentally isolate electronics in harsh environments to satisfy payload trends, reduce development time, and manage the entire technology life cycle.*

Increasing demand for processing on manned or Unmanned Aerial Vehicle (UAV) platforms continually exceeds pressurized space for electronics. Movement of sensitive electronics to unconditioned compartments requires environmental isolation that many platforms cannot provide. Few solutions address the need for cost-effective flexibility in electronics selection and integration in harsh environments. Innovative packaging approaches, such as those utilizing direct spray, provide essential environmental isolation with the ability to mix commercial-grade air-cooled and rugged conduction-cooled electronics in the same enclosure. Besides successfully satisfying today's payload trends, direct spray enclosures offer reduced development time and life-cycle

cost benefits.

### Satisfying payload trends

More than ever, integrators are asked to provide more capability with less Size, Weight, and Power (SWaP), producing power densities in harsh environments that tax traditional cooling capabilities. Intelligence, Surveillance, and Reconnaissance (ISR) applications today relay critical information from the sensor on an airborne platform to the ground for compilation. Trends to reduce dependence on limited data link rates require more computing in the air. Parallel processing, floating and fixed point calculations, and filtering are common tasks performed in payloads such as radar and image processing, electronic

warfare, signal processing, command and control, and mission processing. The ability to configure dedicated hardware with task-specific software using FPGA and DSP products for a wide variety of applications is attractive to leading vehicle integrators.

Unfortunately, such electronics consume 100-200 W per 6U slot (especially VPX), quickly exceeding air- and conduction-cooled enclosure and platform cooling capacity. As technology refresh cycles of avionics range from 8 to 10 years and processing electronics vary from 5 to 8 years, it is inevitable that some electronics will be forced out of conditioned space. Similarly, the growing demand for unpressurized UAVs places an equal burden on

integrators to either ruggedize electronics or otherwise isolate more temperature-sensitive electronics, such as RF cards, from environmental extremes.

Ruggedizing electronics to relocate from stationary ground environments or pressurized compartments to unconditioned space with requirements ranging in altitude from 25,000 to 70,000 feet and temperatures from -65 °C to +71 °C has a significant effect on development schedules. Redesigning, manufacturing, and testing air-cooled boards for conduction cooling can take up to 12 months when industrial-grade component lead times alone exceed 6 months. If rugged air-cooled cards are used, compensation on RF cards is often required due to variations in temperature between first and last cards in the enclosure. Either way, extended development and integration timelines negatively impact the ability to quickly deploy payloads in harsh environments. Furthermore, every platform has different levels of cooling infrastructure, complicating integration when boards only exist in either air- or conduction-cooled configurations, but not both.

Adding functionality and performance unavailable when the electronic subsystems were originally deployed requires upfront planning to limit refresh costs to

electronics, I/O, and software applications. Conduction- and air-cooled enclosures strain to deliver adequate cooling at extreme environments for today's electronics. As technology changes over the next decade, the probability that integrators can use today's enclosures without redesign for tomorrow's electronics is low. When systems are deployed without provision for growth in the form of per-slot cooling, overall heat rejection, or Environmental Control System (ECS) capacity, the cost of technology upgrades becomes significant. Another significant contributor to life-cycle costs is the electronics: Conduction-cooled electronics are typically twice the cost of their commercial-grade, air-cooled equivalents. Direct spray solutions ensure thermal headroom for future upgrades while enabling the flexibility today to deploy any electronics for use in harsh military environments.

### Reducing development time

Air- and conduction-cooled cards are readily installed in direct spray enclosures for integration, testing, and production on military platforms. Aircraft such as RQ-4 Global Hawk (see photo courtesy of Northrop Grumman, first page of article), U-2 Dragon Lady, MQ-1 Predator, and MQ-9 Reaper are taking advantage of

“ For larger airborne enclosures housing 5 to 20 slots, the cost savings in electronics can be five times the added expense of the direct spray enclosure and cooling system. ”

the inherent ability to use commercial-grade electronics in extreme environments, by using direct spray enclosures. In all cases, the electronics are located in unpressurized compartments on platforms with operational requirements as shown in Table 1. Even under such extremes, sensitive RF electronics can be heated and cooled with the ability to minimize temperature gradients to less than 2 °C for a 20-slot enclosure while boards range in power from 20 to 100 W/slot, obviating the need for temperature compensation. For air-cooled enclosures, gradients can be as large as 20 °C from the first to last slot.

Direct spray enclosures take about six months to configure I/O, identify and procure the desired backplane, and test the subassembly prior to customer electronics installation. During enclosure configuration, electronics hardware and software integration is possible in lab environments by mixing commercial-grade air- and/or conduction-cooled boards. Those same lab assets can then be integrated on the platform for further qualification and deployment. Figure 1 depicts the timeline for electronics integration when ruggedization is required relative to commercial-grade electronics in a direct spray enclosure.

### Managing life-cycle costs

General Purpose Processing (GPP) remains a necessary function in deployed enclosures by providing the user interface, system monitoring, and data acquisition running on operating systems

Platform Requirements			
Temperature (°C)	-65 to +71		
Altitude (ft)	25,000-70,000		
Temperature Gradients	Air	Conduction	Direct Spray
$\Delta T^{\circ}C (T_{slot\ n} - T_{slot\ 1})$	20	10	2
Electronics (6U)			
Available Power Density (W/slot)	200	100	Either
GPP Cost	\$8,000	\$15,000	Either
FPGA Cost	\$30,000	\$40,000	Either
Lead Time (weeks)	8-16	26-34	Either
Enclosure			
Available Cooling Capacity (W/slot)	100	100 <sup>1</sup>	500
Cost	\$15,000	\$25,000	\$45,000
Projected Enclosure Capability			
Cooling Capacity (W/slot)	200 <sup>2</sup>	200 <sup>3</sup>	850-1,000
<sup>1</sup> Industry data for conduction. Few applications achieve this power density.			
<sup>2</sup> Industry data for Air Flow Through (AFT) boards and enclosure			
<sup>3</sup> Industry data for Liquid Cold Plate with conduction enclosure and boards			

Table 1

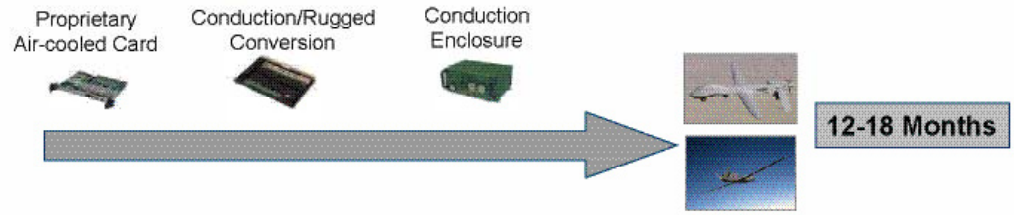
such as XP, VXWorks, or Linux and analyzing the data preprocessed by DSP or FPGA boards. Commercial-grade GPP SBCs range from \$5,000 to \$10,000 per 6U card, while rugged conduction-cooled configurations average \$15,000. When FPGA boards are available in air- and conduction-cooled versions, the percentage difference is smaller at \$30,000 and \$40,000, respectively. Table 2 represents the board cost differential for an integrated enclosure on a per-slot basis.

Direct spray enclosures with cooling system components cost about \$20,000 more than equivalent conduction enclosures and approximately \$30,000 more than air-cooled enclosures in quantities of less than 10 (see again Table 1). In the case of a direct spray, this includes the cooling system, card cage housing the electronics, and enclosure as shown in Figure 2. For air- and conduction-cooled enclosures, the requisite platform-level cooling hardware is not included in the costs presented. The enclosure cost differential between direct spray and conduction is easily overcome when three or four of the boards are air-versus conduction-cooled.

For larger airborne enclosures housing 5 to 20 slots, the cost savings in electronics can be five times the added expense of the direct spray enclosure and cooling system. Costs throughout the life cycle are deemed important, as airborne platforms are expected to have a 30 to 40 year useful life. For KC-135s and B-52s, the reality is greater than 60 years of deployment because the economics of upgrades and refurbishment outweigh the development costs of new planes. Incremental technology refresh cycles are common on today's aging aircraft. Direct spray systems confine refresh costs to purchasing next-generation electronics, configuring I/O, developing software, and tuning the card cage spray for different boards. This is made possible by the inherent thermal headroom of direct spray enclosures.

Direct spray enclosures enable any electronics to be upgraded over multiple refresh cycles with proven power densities

### Traditional COTS Ruggedization Model



### Direct Spray Model

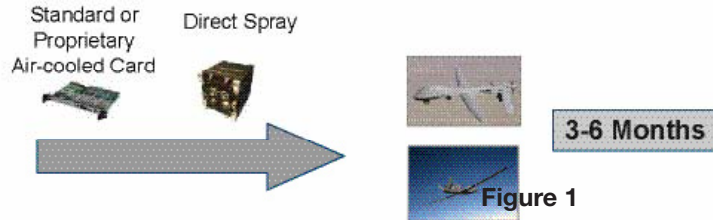


Figure 1

Slot Count	GPP – Air	GPP – Conduction	Cost Difference
4	\$32,000	\$60,000	\$28,000
5	\$40,000	\$75,000	\$35,000
6	\$48,000	\$90,000	\$42,000
7	\$56,000	\$105,000	\$49,000
8	\$64,000	\$120,000	\$56,000
9	\$72,000	\$135,000	\$63,000
10	\$80,000	\$150,000	\$70,000

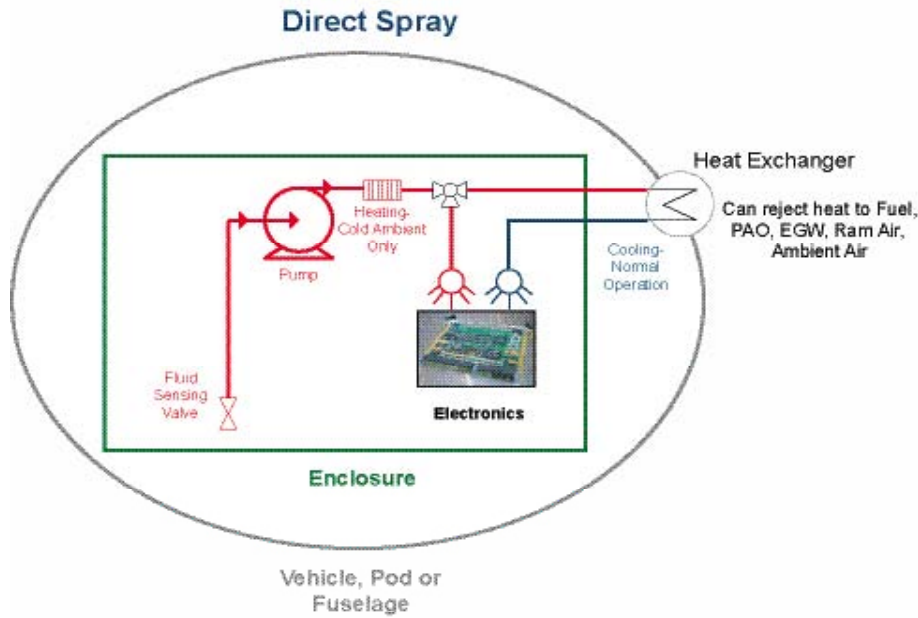
Slot Count	FPGA/DSP – Air	FPGA/DSP – Conduction	Cost Difference
4	\$120,000	\$160,000	\$40,000
5	\$150,000	\$200,000	\$50,000
6	\$180,000	\$240,000	\$60,000
7	\$210,000	\$280,000	\$70,000
8	\$240,000	\$320,000	\$80,000
9	\$270,000	\$360,000	\$90,000
10	\$300,000	\$400,000	\$100,000

Table 2

of 500 W per slot on demonstration boards and industry projections of 850-1,000 W per slot per 6U card. As the overall heat load of a direct spray enclosure increases, a heat exchanger (see again Figure 2) mounted in the aircraft can be scaled to meet the payload requirements. The thermal headroom offered by direct spray enclosures in the foreseeable future provides integrators development and upgrade cost savings. When systems are deployed with provision for growth in the form of per-slot cooling capability and overall heat rejection, the cost of technology upgrades is reduced over the aircraft life cycle.

### Direct spray: Meeting modern demands

Direct spray enclosures support the trend for more processing payloads co-located with the sensors on air platforms, especially for unpressurized, SWaP-constrained UAVs. Subsystem integration time and cost reductions arise from the ability to readily accept air-cooled, conduction-cooled, and custom boards. Because the enclosure and heat exchanger constitute an autonomous subsystem without dependence on cooling infrastructure such as an ECS, platform-level integration is simplified. The ability to integrate and deploy commercial-grade electronics in extreme environments affords



procurement lead time advantages and cost savings. Direct spray enclosures, like those produced by SprayCool, also enable development time and production cost savings. With intrinsic thermal headroom, the cost savings extend over the platform life cycle. ⊕



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tioning, partnership development, and market research. Since joining SprayCool in 2000, he has held engineering and management positions supporting program management, product development, and systems engineering. Prior to SprayCool, he developed control systems and automated equipment for the food processing, agricultural, and HVAC industries. Andy earned a BSME from the University of Idaho, an MS in Engineering from Purdue University, and an MBA from Indiana University. He can be contacted at [afinch@spraycool.com](mailto:afinch@spraycool.com).

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