SPRAYCOOL®

Flexibility in Electronics Selection and Deployment for Airborne Platforms

(Life cycle Cost Analysis and Deployment comparisons)

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ABSTRACT

Vehicle sub-system integrators are challenged to provide enhanced processing capabilities in small, unpressurized space on airborne platforms. Direct spray enclosures offer an alternative approach to environmentally isolate electronics in harsh environments, and give integrators ultimate flexibility in the selection and deployment of the electronics.

BACKGROUND

Increasing demand for processing on manned or Unmanned Arial 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. The white paper will discuss these trends, the development time and lifecycle cost benefits of using direct-spray enclosures to deploy *any* electronics in harsh environments.

Keywords: Airborne applications, electronics cooling, airborne platforms, life cycle cost comparisons, development time comparisons

AIRBONE PAYLOAD TRENDS

More than ever, integrators are asked to provide more capability with less Size, Weight, and Power (SWaP) budget, 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 Watts per 6U slot (especially VPX) quickly exceeding air-cooled and conduction-cooled enclosures and platform cooling capacity. As technology refresh cycles of avionics range from 8-10 years and processing electronics vary from 5-8 years, it is eminent for some electronics to 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 temperature from -65°C to +71°C has significant development schedule impacts. Redesigning, manufacturing and testing air-cooled boards for conduction cooling can take up to12 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-cooled 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 lifecycle costs is the electronics: Conduction-cooled electronics are typically twice the cost of 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.

Platform Requirements			
Temperature (°C)	-65 to +71		
Altitude (ft)	25,000-70,000		
Temperature Gradients	**Air**	**Conduction**	**Direct Spray**
ΔT°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[1]	500
Cost	$15,000	$25,000	$45,000
Projected Enclosure Capability			
Cooling Capacity (W/slot)	200[2]	200[3]	850-1000

[1]Industry data for conduction. Few applications achieve this power density.
[2]Industry data for Air Flow Thru (AFT) boards and enclosure
[3]Industry data for Liquid Cold Plate with conduction enclosure and boards

Table 1 Platform requirements, electronics and enclosure characteristics

SYSTEM DEVELOPMENT TIME

Air-cooled 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, U-2 Dragon Lady, MQ-1 Predator, and MQ-9 Reaper are taking advantage of 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 Watts/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 6 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 with a mix of commercial grade air-cooled and/or conduction boards. Those same lab assets can then be integrated on the platform for further qualification and deployment. Figure 1 graphically depicts the timeline for electronics integration when ruggedization is required relative to commercial grade electronics in a direct spray enclosure.

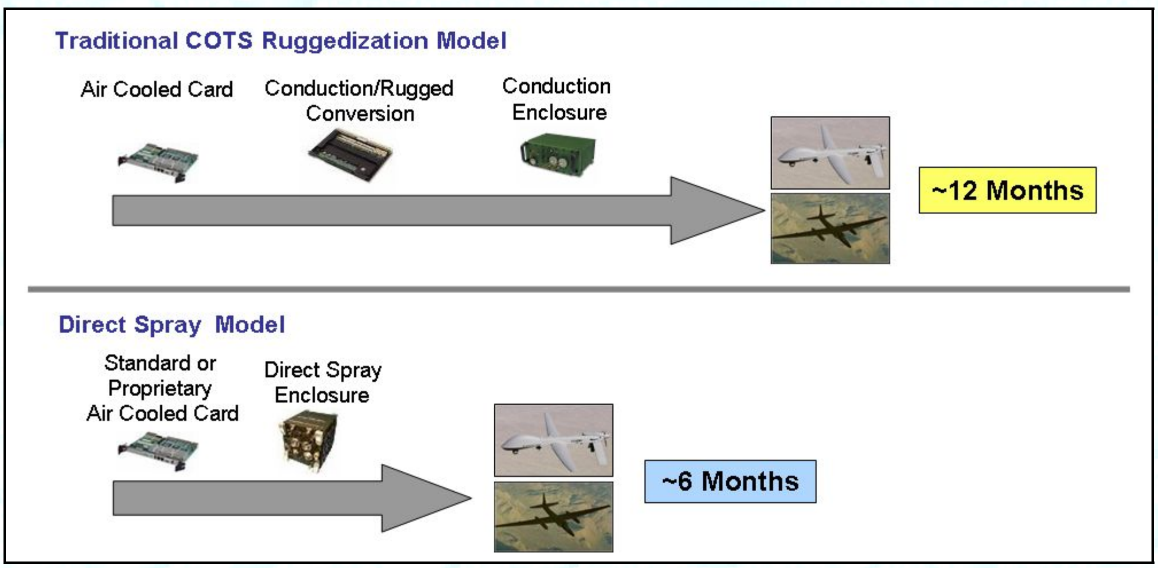

Figure 1 Timeline for integrating electronics on airborne platforms

SYSTEM LIFECYCLE COST

General Purpose Processing (GPPs) remains a necessary function in deployed enclosures by providing the user interface, system monitoring and data acquisition running on operating systems such as XP, VXWorks or Linux and analyzing the data pre-processed by DSP or FPGA boards. Commercial grade GPP Single Board Computers (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 reflected in 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 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 3 or 4 of the boards are air-cooled versus conduction-cooled. For larger airborne enclosures housing 5-20 slots, the cost savings in electronics can be 5 times the added expense of the direct spray enclosure and cooling system.

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 - Air	FPGA - 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 Cost differential between commercial air-cooled and conduction-cooled boards.

Airborne platforms are expected to have a 30-40 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 of 500 Watts/slot on demonstration boards and industry projections of 850-1000 Watts/slot per 6U card. As the overall heat load of a direct spray enclosure increases, a heat exchanger, as shown in Figure 2 mounted in the aircraft, can be scaled to meet the payload requirements. The thermal headroom offered by direct spray enclosures into 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.

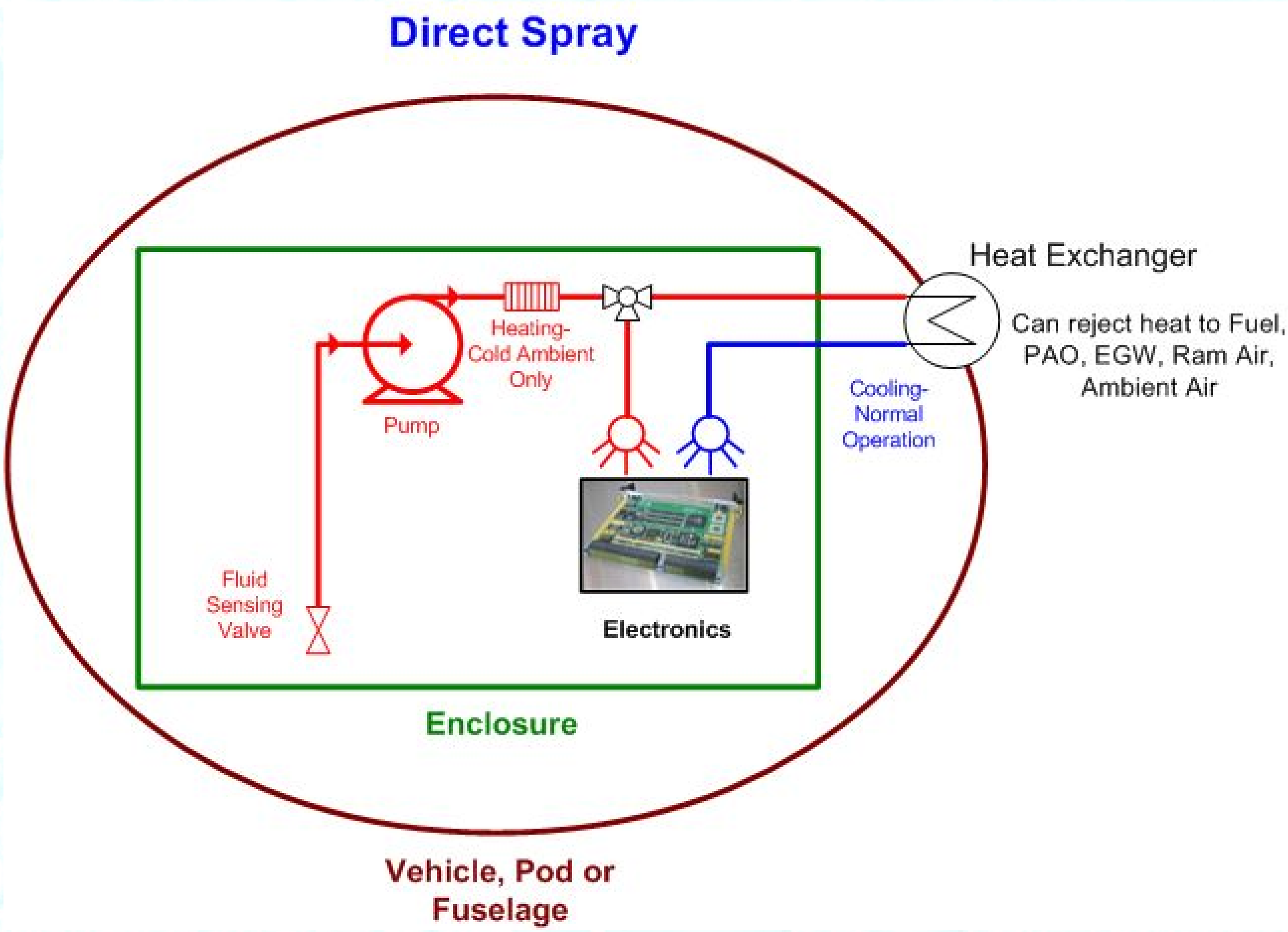

Figure 2 System diagram for direct spray

CONCLUSION

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, enable development time and production cost savings. With intrinsic thermal headroom, the cost savings extend over the platform lifecycle.

For more detailed system level cost comparison, using Direct Spray Enclosures vs other cooling technology enclosures, see companion white papers:

- ***Cooling Commercial Grade Electronics for Use in Harsh Military Environments***
- ***Comparing Platform Level Electronics Cooling Approaches at the Systems Level***