

# The Thermal Management Imperative in Avionics and Defense Electronics

THE ONE TREND THAT CAN MAKE OR BREAK YOUR COMPANY

## **Executive Summary**

The days of testing thermal performance with duct tape and cardboard mockups are winding down. Modern electronic systems cannot be handled on the back of an envelope, and the required pace of innovation is just too fast. The most successful avionics and defense electronics companies are making thermal management expertise part of their DNA. New technologies like upfront CFD software are making it possible for today's multi-tasking engineers to effectively deliver thermal management expertise early in the design process long before physical prototyping and testing.

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## Electronic Life and Death

Avionics and defense electronics engineers are well acquainted with MIL-HDBK-217. This military specification represents a standard methodology for predicting electronic system failures over time. In a nutshell, your electronic system lifespan will be shortened with more components, harder duty cycles, and increased temperatures. Its thermal basis comes from an interpretation of the Arrhenius equation and is often boiled down to a statement such as: “Each 10°C rise in temperature cuts the lifetime of a part by half.”

The exact accuracy of MIL-HDBK-217 predictions has recently come under attack. Regardless of position on that debate, most people recognize that the central theme of thermal impact on life and reliability represents the biggest challenge for modern defense electronics companies. Military equipment must operate in extreme desert heat, arctic cold, and high altitudes where air is thin and ineffective for cooling. At the same time, package sizes are shrinking while power levels are rising.

## It ain't easy... and it's getting harder

Avionics and Defense Electronics is trending from copper based Fly-by-Wire (FBW) to fiber optic Fly-by-Light (FBL) systems. While this move offers huge advantages in weight, cost, design, and EMI protection, it will drive unprecedented thermal demands. The most successful defense electronics companies of the next decade are making thermal management expertise part of their corporate DNA today.

Electronics manufacturers constantly battle the relentless challenge of fitting hotter stuff into smaller spaces. In 1965, Gordon Moore, co-founder of Intel, predicted that the number of components the industry could fit on a microchip would double every 12 months. Commonly referred to as Moore's Law, his prediction was later revised to every 18 months and has basically held true. Moore's Law has opened a whole new world of opportunity for avionics and defense suppliers. Development of newer, faster chips is primarily limited by manufacturing techniques on the micro level and end-user heat removal. Will your company be prepared to respond to customer requirements based upon the latest compute speeds? Can you keep up with Moore's Law?

The evil little secret of Moore's Law is that it tends to drive innovation rather than be driven by innovation. In other words, a blazingly fast new processor will hit the market before all the great new ideas are imagined to exploit its capability. If you understand that new thresholds in processing power are smashed every day, you had better also understand that engineers will absolutely be inspired to create wild new ways of devouring that power. It is impossible to totally predict what your customers will require in the future. Only the companies with thermal design competency hard-coded in their genes will be prepared to capitalize on these new opportunities.

**“Each 10°C rise in temperature cuts the lifetime of a part by half.”**

## Fly-by-Hand

In 1903, Orville Wright lifted off the earth and controlled his craft through what might best be described as Fly-by-Hand. He manipulated levers and cables connected directly to the flight control surfaces with his hands and hips. The Wrights understood the need to control the three primary elements of flight dynamics: pitch, yaw, and roll. To this day, sophisticated avionics systems on enormous jetliners still address those three parameters.

For decades, planes were controlled with increasingly ingenious mechanical systems. All manner of pulley, cable, gear, and control rod were developed. As aircraft got larger and more powerful, the forces needed to move rudders and flaps required the development of hydraulically assisted controls. All of these methods featured a direct mechanical, tactile connection between the pilot and his wing flaps.

## Fly-by-Wire

Purely hydraulic-mechanical systems are bulky, heavy, and tough to package. In the 1960s, researchers began looking to electronics for relief. Small copper wires could replace control rods, cables, and long hydraulic lines to send signals from the cockpit to an electric motor or hydraulic positioner in the distant tail of a plane. Auto-correction algorithms could also be programmed into these systems to assist the pilot and enable smoother, more reliable air travel.

Fly-by-Wire (FBW) birthed a new era of flight controls. Once Aircraft System Engineers tasted the benefits of powerful chip-based feedback and control systems, the demand for data bandwidth skyrocketed.

## Fly-by-Light

### Learning from the Fiber Optics Pioneers

The telecom industry was born of a similar explosion in bandwidth consumption. Information previously carried via Pony Express saddlebag soon made its way through miles of wires in the form of dots and dashes. Bandwidth capacity eventually increased to allow actual telephone conversations. Audio bandwidths gave way to even larger data streams capable of high definition video on demand. How many people on earth now use cell phones on a daily basis? Email? Internet? Cable TV?

Telecom equipment manufacturers met new bandwidth demands by moving from copper to fiber optic data transmission. Fiber optic cabling obliterates the bandwidth bottleneck inherent in copper lines. Massive quantities of data can be transmitted at incredible speeds over dramatically longer distances with remarkably minimal signal losses.

Imagine a 50-foot garden hose internally lined with a perfectly mirrored surface. Now point a flashlight in one end and flick it on and off for an old fashioned Morse code message. Someone at the other end could easily read the message by

## Consider the Bionic Plane

Imagine a system of sensors that could continuously measure and broadcast stress, strain, temperature, and vibration readings on every inch of an aircraft's skin and substructure. If sufficient communication bandwidth and computer horsepower were available, that data could be used for real time health and reliability calculations. Stepping even deeper into science fiction, think about an army of nano-machines instantly deploying to make repairs and strengthen failing components identified by that real time feedback.

The wonderful thing about Moore's Law is that it makes all these things possible. It will put the Bionic Plane on someone's design horizon, but Moore unfortunately did not give us a thermal design companion guide.

watching the resulting light pulses. Now shrink the hose to the diameter of a human hair, stretch it out over 50 miles, and learn to thumb your flashlight's on/off switch a few billion times per second. Welcome to the world of fiber optics!

## Fiber Optics in Avionics

The demand for data flow in modern aircraft is already outpacing the capabilities of copper wire. As in telecom, avionics and defense manufacturers are transitioning to fiber optic platforms that can easily transmit a thousand times the bandwidth available over copper. A few developing fighter jet programs use fiber optics for actual flight control. In commercial aviation, optical fiber is limited to primarily non-flight control applications. Fiber optics has long been proven in telecom, so why has it been so slow to catch on in avionics?

- **Failure effects:** Failure in a telecom device might result in dropped telephone calls or huge revenue losses from disrupted business transactions. Failure in avionics equipment can result in planes falling from the sky.
- **Operating conditions:** The environmental conditions (humidity, temperature, vibration, etc.) for telecom equipment can be well-predicted and controlled. Not so in aerospace and defense applications.
- **Market size:** The avionics market is a fraction the size of the telecom market. The R&D expenditures needed to fortify telecom equipment and specs to satisfy transportation requirements have been tough to justify

Fiber optics offers many other great benefits for aviation and defense beyond just expanded bandwidth. Copper based systems require heavy shielding to protect against electromagnetic interference (EMI). Fiber optic cabling is totally immune to EMI without any special shielding. As the threat of EMI based attacks on commercial aviation grows, it is likely that the FAA will require higher shielding standards that will demand deeper investment in FBL systems. FBL also eliminates typical FBW concerns such as corrosion, cross-talk, and short circuiting.

FBL promises to stress the already tenuous thermal situation for systems engineers and suppliers in several ways:

- If the data flow possible with copper wiring is like drinking from a straw, fiber optics offers a wide open fire hydrant. The electronic equipment processing all that data will be much more powerful and generate significant new heat levels.
- FBL requires the addition of optical/digital converters. These represent a new heat source that will have to be accounted for in cooling systems.
- The great advantage of EMI immunity in fiber optic cabling will make it possible for systems engineers to concentrate all the remaining EMI-sensitive equipment in centralized, highly-shielded locations... more hot stuff in tighter spaces.

**“FBL promises to stress the already tenuous thermal situation for systems engineers and suppliers”**

## Beating the Heat

Electronics today are called upon to do more and more in modern aircraft. Avionics suppliers today are required to develop mission critical devices that must operate no matter what. With bandwidth advances in the current generation of FBW systems and the even bigger demands coming with FBL, suppliers will need to make thermal management a core competency.

New technologies like upfront CFD (Computational Fluid Dynamics) software are making it possible for today's multi-tasking engineers to effectively deliver thermal management expertise early in the design process long before physical prototyping and testing.

### Upfront CFD

In the 1960s, academic researchers began to simulate thermal and fluid flow phenomena with some of the earliest digital computers. They were meticulously solving massively complex mathematical equations with punch cards! By the 1980s, advances in computer horsepower created a market for CFD in industrial applications. These traditional CFD software tools could be used only by highly-skilled, dedicated PhD analysts and generally had little impact on R&D for current projects. Traditional CFD tools are still used heavily in industry today, but the emergence of upfront CFD has enabled frontline design engineers to take advantage of this technology in the earliest stages of product development.

Upfront CFD delivers the solver technology proven reliable in traditional CFD, but packaged within a highly-automated framework ideal for 3D CAD users and multi-tasking engineers. Traditional CFD is inherently divorced from frontline product development because of its complexity and required specialization.

Upfront CFD is built for multi-tasking engineers who lack the time or inclination to dedicate themselves to traditional CFD. Upfront CFD is a simple extension of the CAD technology and expertise that frontline design engineers use every day. It is much easier to promote within these ranks and the best way to naturally inject thermal competence into every level of the organization.

### Key traits of upfront CFD:

- CAD based: All geometric manipulation is done in the CAD tool rather than a separate modeling tool.
- Automation: meshing and analysis setup must be far more automated than traditional CFD or multi-tasking engineers will not accept it.
- Hardware transparency: the underlying solver technology must enable solution delivery on the same PC the design engineer uses for CAD.
- Design Review: Traditional CFD focuses on long-term research. Upfront CFD provides the insight needed for quick, seat-of-the-pants design direction decisions. Multi-tasking engineers require design review tools that allow immediate, interactive comparison of a portfolio of design options.

## Defense Electronics Case Study Sechan Electronics

[www.sechan.com](http://www.sechan.com)

Sechan Electronics was tasked with developing a new digital fire control system for the Paladin self-propelled Howitzer. The system required a single chassis to house three single board computers and associated hardware. The design, however, called for a completely sealed chassis. Fans were not going to be an option, so dealing with thermal performance became a critical concern for the project.

Jim Smith, Lead Mechanical Engineer, recognized that an efficient upfront simulation platform would be needed to provide the required thermal insight to meet the tight project deadline. Upfront CFD provided a direct link to Sechan's CAD tool and could be quickly integrated into the established design process.

Smith used the parametric relationship between upfront CFD and his native CAD assembly to evaluate several design alternatives. Additionally, simulations were conducted on the heat pipe assembly and components and the single-board computer frames to minimize the weight while maintaining an acceptable delta T and structural robustness. "The integration with our CAD tool was excellent and essentially transparent. We were dealing with fairly complex geometries and assemblies without incident," stated Smith, adding that, "meshing was painless and predictable."

Smith says putting CFD upfront in the design process allowed Sechan to eliminate the costs associated with two rounds of prototypes and, more importantly, "We achieved our objective four months faster than if we had relied on traditional prototyping and testing methods." Another advantage of using upfront CFD, according to Smith, is seeing the total product performance picture. "There's no way data from a collection of thermocouples could have given us the same level of knowledge and confidence about our design."

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**— Jim Smith**  
*Mechanical Engineer*

## Defense Electronics Case Study Macrolink

[www.macrolink.com](http://www.macrolink.com)

George Hendershot and the product development team at Macrolink use upfront CFD to conduct early-stage flow and thermal analyses on ruggedized electronics enclosures for avionic, mobile, and fixed applications. They engineer rugged ATR chassis, COTS chassis, portable rugged workstations, and SCSI & Fibre Channel storage systems to meet the most demanding environmental requirements.

“What the tool does for us is really key,” explains Hendershot. “It helps us determine the placement of the fans, the type of fans, the location of the card cage, the density of the air filter, and EMI ventilation panels. We get to do all that sizing upfront in the process.”

A recent project for the Navy involved the creation of an airborne transportation rack (ATR), which could house a radar system for Navy ships. As the unit developed, Sam Suh, Senior Mechanical Engineer at Macrolink, optimized the thermal characteristics of the system by rapidly assessing numerous design modifications within the MCAD environment. Upfront CFD simulation provided Suh interactive 3D visualization of airflow as it enters the box, flows through the card cage, and circulates through the system, including the effects of cables and other system components.

Next, Suh ran a number of simulations on the individual slots to determine the proper opening size of the card cage. When early CFD results revealed a few hot spots, he made adjustments to his MCAD assembly and used upfront CFD to quickly visualize the effects of those changes. “With upfront CFD, I can manipulate the air flow and optimize the design long before I cut any metal,” explains Suh. “Knowing how many watts per slot, I can control the airflow distribution much better.”

Suh believes tight MCADA integration is one of the strongest benefits of upfront CFD. He says he had previous experience using a traditional CFD package that required him to employ file translation methods on his solid models, an error-prone process, to get geometry into the analysis environment.

Upfront CFD has not only improved the product development process at Macrolink, it is having significant impact on the way business is done. “Upfront CFD is integral to our process for partnering with customers,” says Hendershot. “Even in the proposal stage, we’re doing things like sizing up fans and looking for power supplies. It has been a phenomenal asset for us.”

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— **George Hendershot**  
*Mgr, ATR Business Unit*

# Profiting from the Thermal Imperative in Defense Electronics

Existing mainstream technologies like 3D CAD and upfront CFD are proven, effective thermal design tools for avionics and defense electronics. They are best applied as a pervasive core competency throughout design and engineering departments, rather than bottlenecked in the hands of a few specialists.

Proper implementation of these technologies requires investment, training, and executive support. The advantage of starting now is that problems, like those faced by Sechan and Macrolink, can be efficiently addressed today. At the same time, the company will be developing the core thermal competence necessary to tackle the thermal challenges of tomorrow. The leaders in these demanding industry segments will realize that their ability to deal with increasing thermal loads will largely define business success or failure.

Given the relentless nature of Dr. Moore's Law, a well-advised next step is to investigate technologies like upfront CFD to provide your business with a short-term competitive advantage and assurance of long-term survival.

## About Blue Ridge Numerics, Inc

Blue Ridge Numerics, Inc. is the leading provider of fluid flow and thermal simulation tools for mechanical engineers. Its upfront CFD tool, CFdesign, was the first built from the ground up for multi-tasking design engineers. With recent recognition from Inc 500 and Deloitte & Touche as one of the fastest-growing private companies in America, Blue Ridge Numerics continues to alter the way CFD is deployed in top companies around the world. Please see [www.cfdesign.com](http://www.cfdesign.com) for details.

## About the Author

Jeff Waters began his engineering career at General Motors, where he introduced a variety of specialty and early CAE technologies for simulation-based stress, strain, thermal, and flow R&D. In 1999, Waters joined Blue Ridge Numerics, Inc. to help manufacturing and product development companies efficiently implement upfront CFD. Waters is a graduate of Rose-Hulman Institute of Technology. He can be reached at [jeff.waters@cfdesign.com](mailto:jeff.waters@cfdesign.com).



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