CHALLENGES IN THE DESIGN AND IMPLEMENTATION OF AIRBORNE TELEMETRY PROCESSING SYSTEMS

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ABSTRACT

While typical telemetry processing systems are fixed, ground-based assets, certain mission profiles or telemetry acquisition models may involve telemetry processing systems which reside on other platforms, such as ships, mobile vehicles, or airplanes. The design and implementation of telemetry processing systems for these platforms poses unique challenges, which may include requirements for unusual mechanical packaging, heightened electromagnetic sensitivity, or specialized electrical interfaces. This paper presents some of the key challenges involved in the design and implementation of an airborne telemetry processing system and discusses how lessons learned from solving these challenges may be applied to future telemetry processing system designs.

KEY WORDS

Ruggedized hardware; airborne system; ATR chassis; MIL-STD-810.

INTRODUCTION

The conventional modern architecture for telemetry processing systems began to emerge in the mid-1980s with the development of systems like NASA's TCDS (Telemetry and Communications Data System) and NCPS (Network Command Processing System). With the evolution of commercial x86-based computer systems in the early 1990s, telemetry systems converged towards the 19-inch rackmount computer server as a common form factor, with the average system footprint usually being around 3U to 4U. Over time, this form factor has in many cases shrunk to a 1U to 2U system, largely as a consequence of a reduced need for custom hardware interfaces, but has otherwise remained the default for a typical ground-based telemetry system.

Despite being ubiquitous within ground segments around the world, conventional rack-mounted telemetry capture and processing systems are not suitable for every mission profile; many missions, particularly within the defense sector, require mobile telemetry processing capability that can be transported on a variety of platforms, including aircraft, ships, or ground vehicles.

While attempts have been made to utilize conventional telemetry processing systems in these roles, it is typically difficult for such systems to operate within the extreme environments often posed by mobile platforms. Consequently, providing reliable telemetry processing capability for these missions can require the design and implementation of a completely new system architecture, which is designed from the ground up to meet the unique environmental requirements of a particular target platform. Such designs pose a number of unique challenges which are not present in the design of conventional, ground-based telemetry processing systems.

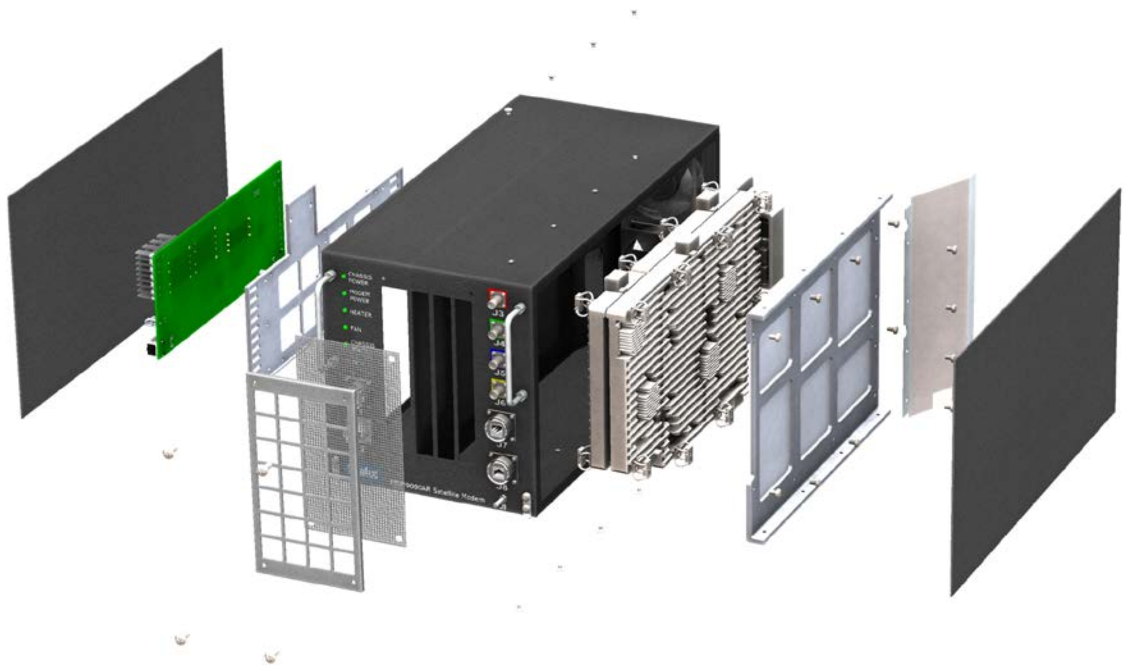

Figure 1: Airborne Modem – Exploded View

Figure 1 shows an exploded view of a representative airborne modem / telemetry processor, which will be referenced as a case study in this paper. The example airborne modem includes many of the same commercial off-the-shelf (COTS) components that might be included in a conventional, ground-based unit; however, these components are integrated into a specialized Aircraft Transport Rack (ATR) chassis, and are coupled with specialized environmental control hardware that manages the environment inside the chassis. The integrated unit is designed to meet the MIL-STD-810 [1] and DO-160C [2] standards for deployment and operation aboard a typical military aircraft.

DESIGN AND IMPLEMENTATION CHALLENGES

The ruggedization of COTS components for use in an airborne system presents many design challenges; when equipment that is designed for use in a commercial environment is used in airborne applications, care must be taken to ensure that the commercial equipment is not exposed to environmental extremes it was not designed to handle. Typical environmental and operating challenges for airborne deployment include:

- Temperature: COTS electronics are typically designed to work in a temperature range from 0°C to 70°C, while the operating temperature range for avionics is typically from -45°C to 120°C. Further, while conventional electronics are typically deployed in a temperature-controlled environment, such as an enclosed server room, this is not the case for airborne electronics, which often experience rapid changes in temperature as an aircraft maneuvers.

- Airflow: Unlike a conventional server room, which typically features extensively filtered airflow, the operating environment on board an aircraft can contain extreme amounts of dust, sand, and other particles. In addition, airflow on board the aircraft can vary wildly depending on the specific flight profile and operating altitude.

- Vibration: For typical commercial electronics, vibration is not a concern during operation. Avionics are regularly exposed to vibration extremes while an aircraft is in flight; the vibration parameters specified in the DO-160C and MIL-STD-810 specifications are well outside the operating range of most COTS equipment.

- Pressure: COTS ground electronics, which remain at a fixed altitude, rarely need to operate with any pressure change at all, much less the variable pressure environment specified in DO-160C.

- Power: +28V DC is a common power source used in avionics, and commercial equipment used in avionics must be adapted to this power source. Additionally, commercial electronics must be designed to comply with EMC, EMI, and static electricity requirements specific to the environment on board an operating aircraft.

- Humidity: Commercial electronics may require modifications to handle the humidity requirements that avionics are commonly subjected to while an aircraft is in flight.

The following sections discuss several of these key challenges, and present some of the unique solutions necessary to address them.

KEY CHALLENGE: TEMPERATURE

Commercial electronic components and assemblies are typically designed to be operated at a significantly narrower range of temperature extremes that is typically found in avionics applications, and use of such components on board an aircraft requires an enclosure that keeps the commercial equipment within a safe temperature range. Doing so requires active monitoring and control of temperature, as well as fail-safe power control to ensure that the electronic components are not operated when the temperature is outside of the acceptable range.

In designing the representative airborne modem, a number of discrete measures were adopted to provide resilient temperature regulation for the commercial electronic components, which included a set of particularly temperature-sensitive demodulator boards.

As a first step, the components were enclosed within a custom-machined solid aluminum heatsink superstructure. Adding heat dissipation fins to the surface of the superstructure enabled the boards to effectively conduct heat into the aluminum, which then transfers this heat to an air stream forced across the reverse side of the superstructure. The components would normally be cooled by direct convection; this convection process was thus transferred to the aluminum superstructure. A thermal analysis of this cooling mechanism is shown in Figure 2.

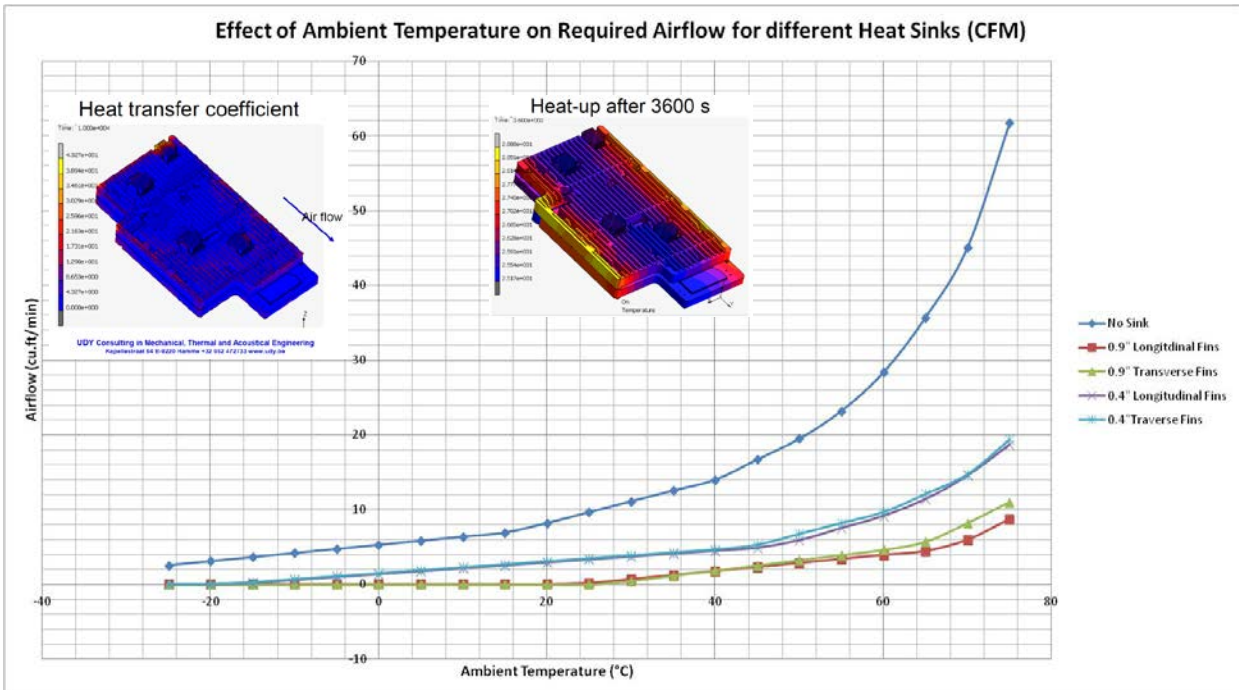

Figure 2: Thermal Analysis

In order to ensure sufficient heat transfer between the heat-generating board circuits and the aluminum structure, gap padding and pyrolytic graphite sheeting were added to the demodulator boards, simultaneously electrically isolating the board components from the superstructure and providing high thermal conductivity across the connection gap.

However, purely passive temperature control is not sufficient to meet the environmental requirements for airborne operation, particularly on the lower end of the aircraft's ambient temperature range. These controls were therefore augmented with a dynamic active temperature regulation mechanism. Inside the representative modem, an embedded controller (shown in Figure 3) monitors, in real time, the variations in its own temperature, the temperature of the demodulator boards and the aluminum superstructure, and the system intake and exhaust air temperatures.

Figure 3: Thermal Controller

Using this data, the controller autonomously controls power relays that feed current to the modem components, integrated heating elements, and system ventilation fans, providing dynamic temperature adjustment and preventing the temperature-sensitive components from being powered on if the temperature is outside their safe operating range.

KEY CHALLENGE: AIRFLOW

To ensure sufficient airflow through the modem chassis, and particularly across the superstructure, a number of changes were required to the internal air distribution channels within the chassis; the changes, which are shown in Figure 4, ensured that airflow was biased to the superstructure and more equally directed across both sides of it.

To accommodate the extreme airflow through the system, a custom filter was designed to provide sufficient air inlets while preventing dust and debris from penetrating the unit. The filter was designed as a large, rectangular orifice in the middle of the front of the chassis, and consisted of a filter frame with thumbscrews at each of the four corners, which was designed to secure filter material behind the frame. The filter material chosen was corrosion-resistant 316 stainless steel wire cloth, woven in a 200 x 200 mesh, with a 0.0016" wire diameter.

While providing excellent dust filtration, this lightweight filter fabric proved insufficiently rigid to remain properly positioned inside the filter frame. As a result, a supporting structure was designed to permanently encase the filter fabric; the filter material is sandwiched between two layers of aluminum sheeting with large, square openings that mimic the openings in the filter frame.

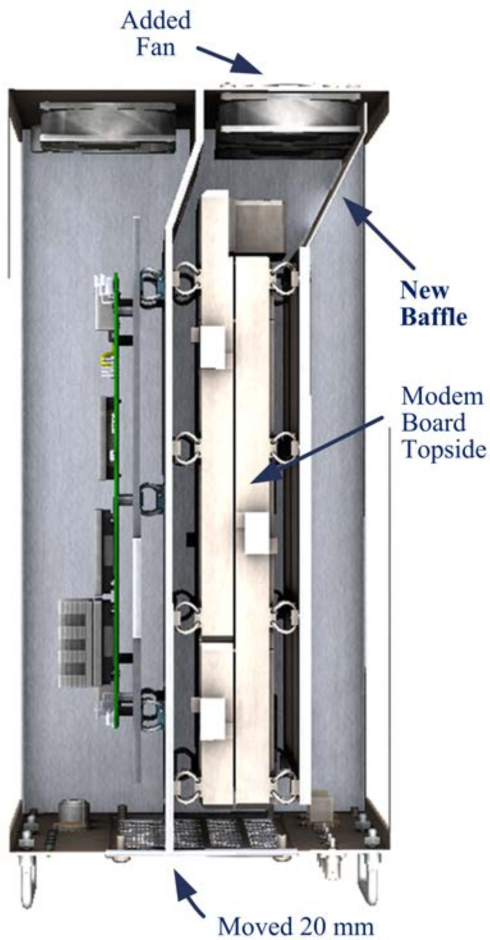

Figure 4: Internal Airflow Channeling

KEY CHALLENGE: VIBRATION

A number of the commercial components utilized in the representative modem design are highly sensitive to vibration. In particular, the modem includes a two-part demodulator board assembly, with a mechanically vulnerable connector joining the two circuit boards. In order to protect this connector, the aluminum superstructure, which encases the boards, provides structural support on both sides of the circuit boards and eliminates stress on the board set connector, which cannot endure any flex. Further, the entire superstructure assembly is mounted within the system chassis using wire rope isolators, preventing direct transfer of shock and vibration to the assembly.

Vibration isolation became a significant challenge during the final assembly of the modem chassis. Cable routing required careful planning to avoid excessive wiring inside the chassis but to allow sufficient slack for components mounted on isolators to move without stressing cable attachments to components that were not vibration-isolated, such as the fans and front panel connectors. Further, cables required secure routing mechanisms to prevent gradual movement over time. This objective was met by adding tie-down points for cables that were integrated with isolated components, eliminating the possibility of relaxed cables striking isolated components during operation.

CONCLUSIONS

The design of the representative airborne telemetry system described in this paper showcases some of the key design challenges and principles involved with airborne equipment, including unique design elements to account for environmental constraints and extremes with respect to temperature, airflow, and vibration. The demanding operating environment on a typical aircraft imposes requirements that are not commonly encountered in conventional telemetry system design, and forces system implementers to consider unique solutions to address them.

At the same time, the representative design demonstrates that a fully aircraft-qualified system can be developed using many of the same COTS components that would be present in a conventional, ground-based telemetry system. Such component reuse reduces the cost and risk of developing airborne systems by allowing significant system elements – including, in many cases, entire boards and assemblies – to be adapted from existing, operationally qualified telemetry systems.

REFERENCES

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[2] SC-135 RTCA, Inc., *Environmental Conditions and Test Procedures for Airborne Equipment*, RTCA DO-160C, Dec 1989.