



# DEPLOYING COMMERCIAL ELECTRONICS AT HIGH ALTITUDE

WHITE PAPER

## ABOUT ATRENNE INTEGRATED SOLUTIONS

Atrenne Integrated Solutions® is a vertically-integrated, component and system provider serving aerospace, defense, computing, communications, and other technology-driven industries. Atrenne delivers integrated components, electronic packaging, fabricated metal, electronic assemblies and value-add build-to-print manufacturing services to industrial markets across the globe. With more than 40 years of experience, Atrenne provides innovatively engineered products and services throughout the program lifecycle, from concept to manufacturing to obsolescence management. Atrenne is proud to provide customers with fully-tested, reliable, electromechanical solutions on-time and with world-class quality.

# DEPLOYING COMMERCIAL ELECTRONICS AT HIGH ALTITUDE

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## DEPLOYING COMMERCIAL ELECTRONICS AT HIGH ALTITUDES

*This paper will demonstrate how to successfully deploy a SWaP-C-optimized full-motion video processing ISR system with commercial components in a high-altitude airborne platform. These types of applications present many challenges including extreme temperature ranges, varying atmospheric pressures and high levels of vibration. Commercially available components are simply not designed to be deployed in high-altitude military and aerospace applications. Introducing COTS components into these applications creates additional challenges that Atrenne was able to solve, reducing cost and time to market compared to custom ruggedized solutions.*

### INTRODUCTION

Airborne intelligence, surveillance and reconnaissance (ISR) via manned and unmanned aircraft (UAV and AV) have become essential to military and security operations.

*Airborne intelligence, surveillance and reconnaissance (ISR) has become a critical factor in the conduct of military or security operations. Although related programs must contend with the reality of defense spending cuts in the West, there is also significant activity in airborne ISR in other parts of the world.<sup>1</sup>*

As IT Security departments try to reduce their exposure to attack, ISR missions have been driven to higher and higher altitudes in an effort to reduce the risks of detection and the potential of being a target. In order to compensate for the higher altitudes involved, greater image quality is required. In the face of technological advancements, working with reduced military budgets, and aging systems in the field, new ISR applications have to meet schedule and cost constraints while providing increasingly complex computing to intelligence personnel.

Historically, ISR engagements (often involving images or motion video requirements) have had to rely on ruggedized components due to the extremely harsh conditions in which the equipment needs to function and nature of the missions involved. Although some ruggedized hardware exists for older applications, modern military programs require leading-edge capabilities utilizing semiconductor and board solutions that have yet to be manufactured in ruggedized form. Because of the smaller production volume of required components, the lengthy process to manufacture and approve such components greatly restricts the agility of military applications. The option to develop application-specific hardware is no longer practical as custom hardware costs and time lines are rarely acceptable.

The value of Commercial Off-the-Shelf (COTS) components has been noted by publications over the years, including:

*By implementing a COTS solution, these programs were, in general, able to demonstrate significantly shorter development schedules, resulting in accelerated implementation and faster fielding. This resulted in being able to use the latest commercially available technology, with significantly reduced lead times<sup>2</sup>*

While commercial hardware is lower-cost and available off-the-shelf, it is challenging to deploy at high-altitude because it is not designed specifically to perform in the extreme conditions found in these airborne platforms.

Using a high-altitude airborne application as an example, Atrenne's supply chain relationships and management practices facilitate a new approach to ISR environmental isolation which takes advantage of commercial components while speeding production, lowering overall cost, and expanding technology options to include the most recent technological advances.

### USING COMMERCIAL COMPONENTS IN MILITARY PROGRAMS

#### Advantages:

- Leading edge road map
- Widely available
- Cost effective

#### Disadvantages:

- Uncertain life cycle longevity
- Not rated for operational temperature range
- Not rated for altitude/pressure requirements
- Typically used with forced-air convection cooling
- Possibly sourced from brokers or off-shore
- Modules typically designed to IPC Class 2



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## THE CHALLENGE

Atrenne was challenged by a customer/system integrator under a tight deadline and strict budget to develop a high-quality, full-motion video (FMV) processor system. The requirements included utilizing both commercial and industrial temperature silicon components that would function successfully and reliably under adverse high-altitude conditions, including extreme temperature ranges, variations in atmospheric pressure, and shock and vibration. Because the customer was only able to present high level requirements, we needed to collaborate with them closely throughout the design and qualification process to determine the final specifications of the product to properly address thermal, vibration, atmospheric and altitude conditions.

Higher-altitude requirements for this project necessitated the use of a more powerful PCI frame grabber than was currently available in a ruggedized form-factor which necessitated the use of a commercial product. Using commercial-grade COTS equipment in this adverse environment presented a variety of engineering challenges. The required components were not designed to accommodate the extreme environment present at high-altitude. Furthermore, the preferred components were from an overseas supplier and thus needed to be authenticated and fully traceable. Commercial components and boards have indeterminate life-cycles, which introduces the very real risk of product obsolescence during the life of the high altitude program.

The final product also needed to meet rigorous SWaP-C (Size, Weight, Power, and Cost) and MIL-STD (Military Standard) requirements.

These requirements included:

- Altitude to the lower stratosphere, well above 50,000 feet
- Operational range from -32°C – 55°C
- Survival range from -40°C – 71°C
- Weight limit of 13 pounds
- MIL STD 810 Shock and Vibration Standards
- Cooling surfaces limited to chassis baseplate-to-fuselage conduction



Atrenne produced a rugged chassis capable of protecting commercial electronics at stratospheric heights.

## HIGH LEVEL SOLUTION

Atrenne's 40 years of building advanced backplanes, chassis, and packaging solutions for rugged, high performance applications combined with an extensive ecosystem network of partners and vendors enables a solid approach to problem solving and delivers a one-stop-shop experience for the customer / system integrator. Our greatest strengths lie in our breadth of engineering talent, lean manufacturing processes and the employment of a strict functional project management approach.

In evaluating the situation, Atrenne determined the best approach would be to encase commercial hardware in a sealed rugged enclosure. Using COTS hardware would allow the customer to take advantage of cost savings while enabling use of the latest technology. This would enable the system integrator to be more agile and use the most advanced technology commercially available.

Atrenne's innovative solution called for a SWaP-C-optimized hybrid of a commercial and ruggedized high altitude ISR system that would mitigate any issues introduced by the non-rugged, off-the-shelf silicon components and modules. The ruggedized system would allow for the use of non-rugged COTS boards and many standard components by hermetically sealing the chassis connectors and fibre optics cables.

This approach would allow the COTS components to function in a temperature and atmospheric pressure consistent with a typical lab environment. Our solution also incorporated workmanship standards, emissions and interference testing, and stress tests for vibration, shock, and temperature. With a robust enclosure design, the system was able to meet these requirements by isolating sensitive internal electronics from the harsh external environment. Third party testing facilities were used to test and confirm that the solution met rigorous MIL-STD requirements, including:

- MIL-STD-461E EMI radiated and conductive emissions - Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
- RTCA-DO-160D - Environmental Conditions and Test Procedures for Airborne Equipment
- MIL-STD-704E - Aircraft Electrical Power Characteristics
- MIL-HDBK-454B - General Guidelines for Electronic Equipment
- MIL-STD-454 Workmanship standards
- MIL-STD-810G - Environmental Engineering Considerations and Laboratory Tests





# RUGGED & READY

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## THE PROCESS

After reviewing the system requirements, and initial risk assessment, Atrenne determined that the product could be delivered on-time, on budget and meeting the technical requirements by facilitating a high degree of collaboration with the customer / integrator and partner vendors. At the forefront of the process were the Program Reviews and Technical Interchange Meetings (TIM), where current status, progress, key issues, and concerns were tracked and discussed. Atrenne has developed a repeatable process to seal almost any COTS equipment for aerial use within a chassis enclosure. Design Reviews including preliminary and critical reviews, followed by Manufacturing Readiness Reviews (MRR), were conducted to determine if there were any gaps with suppliers, partners, and management practices. These meetings identified the challenges that would have to be overcome. Below is a summary of critical issues:

## THERMAL REQUIREMENTS

A B2 bomber, downed in Guam in 2008 by heavy rains that compromised the plane's electronic systems, showed that it is important to address problems related to moisture and temperature (especially for COTS electronics) in aerial applications. For this project, the equipment needed to include not only heating elements for the enclosure (a brief, heat-up period was required before power-up), but heat dissipation for the semiconductor components in use (to prevent overheating).

Part of the challenge with utilizing state-of-the-art systems with multi-processor and multi-core technology in small form factors is that, with a strict power budget, there is excess heat generated. Atrenne provided an innovative heat sink, which utilized a copper piping enclosure with a porous sintered material in the middle. We also added a chromatic liquid into the closed system that would evaporate (at the chip contact point) and then condense as it moved through the pipe via the porous material. The result was a capillary action that effectively transferred heat to the only avenue available for dissipation — the baseplate of the chassis. With this novel design, we were able to deliver superior thermal performance in this conduction-cooled enclosure.

Another significant challenge was ensuring the equipment would operate in the subzero temperatures found at high altitudes. The system integrator required that the system provide a specific window of time from power-on to an operational state. Because the maximum draw of the system was restricted to 100W or less, Atrenne engineered a circuit to prioritize the heater circuits at power-on until the operating environment reached 0°C, at which point the heater would switch off and the system would boot.



Cooling a high-performance CPU in a baseplate-cooled application requires a highly optimized heat sink.

## SHOCK AND VIBRATION

Testing determined that some COTS parts were not up to the demanding environmental requirements of high-altitude. Atrenne discovered issues due to vibration during testing, and was able to eliminate unnecessary and troublesome components and source more robust parts. Our close communication with the customer allowed them to iterate on and improve the design so that the revisions passed the MIL-STD-810 requirements.

## SEALING THE CABLES AND INTERCONNECTS

Atrenne needed to develop creative solutions to hermetically seal fiber optic cables, I/O cables, and connectors, including power input connectors. We collaborated with our ecosystem partners for portions of the project, and the collaboration led to a complete solution for all these components. A key element was determining that standard manufacturing procedures could produce parts that would meet the needs of rugged environments. For elements like fiber optic cables, which were simply fed through a board to fit into a connector, we utilized an epoxy over-mold to properly seal the equipment. Once the design verification was proven, environmental stress screening protocols were implemented to ensure each system met shock, vibration and temperature requirements.

## SIZE, WEIGHT AND POWER

The requirements for the project included strict limitations on the size and weight of the final product as well as the maximum power it can draw. Atrenne utilized a small-form mini-IPX motherboard in a ruggedized enclosure whose final dimensions were within these SWaP-C restrictions.

- Length: 11.22"
- Width: 9.06"
- Height: 3.43"
- Weight: 13 lbs.
- Power Consumption: <100W DC



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## ATRENNE'S KEYS TO PROJECT SUCCESS

### Innovation

Atrenne's relationships and management practices allow for a new approach to ISR environmental isolation that entails repeatable and transferable principles which can speed production, lower overall cost, and expand technology options to include the most recent advances.

### Unparalleled Partner Collaboration

Atrenne's ecosystem of diverse partners allows us to draw on great stores of expertise to solve problems quickly and effectively. These experts partner with Atrenne and work within our program management process to deliver solutions, not just components. For this project, partners worked closely with us to deliver critical data I/O connectors for the COTS products. They addressed discrepancies with gasket materials for enclosure sealing, and assisted with input line filter manufacturing for hermetically sealing the line filter with integral power connectors, to meet MIL-STD-461.

### Design Excellence

Atrenne has been developing advanced backplanes, chassis, and packaging solutions for rugged, high performance applications for over 40 years. In-house capabilities include electrical and mechanical engineering, software development and systems design. We have received Supplier Excellence Awards from industry leaders including GE Aviation, Rockwell-Collins and Raytheon, and has a proven track record of delivering market-leading solutions to our satisfied customers.

### Unique Manufacturing Capabilities

Atrenne is a market leader in providing COTS chassis and enclosure solutions for mission- and performance-critical markets deployed in the world's harshest environments. We are the partner of choice for enclosures, backplanes, and application-specific engineering solutions. Atrenne is also your one-stop shop for chassis components, complex build-to-print manufacturing, control panels, metal fabrication and integration.

Atrenne Integrated Solutions' world-class LEAN Manufacturing program goes beyond simply employing traditional LEAN tools and techniques. The implementation of the LEAN Manufacturing program has resulted in more organized operations on every level and continuous improvement in throughput, customer satisfaction, quality, and delivery times.

## ELIMINATING COUNTERFEIT COMPONENTS

Atrenne worked with the customer to identify and engage an approved screener. All the required parts were bought in a lot from an approved manufacturer, and each individual component was subjected to a screening test and procedure to uncover evidence of tampering, relabeling and similar issues.

## COMPONENT OBSOLESCENCE MANAGEMENT

Commercial components generally have a life cycle of one 1-2 years. Components from a silicon supplier's industrial road map may be marketed for a 5-7 expected longevity. Military programs may have a considerably longer life cycle (10 years, 20 years, ...) so it is essential for a program to consider how to approach component obsolescence challenges. If components or boards adhere to open standards, then subsequent program funding phases can include an upgrade to newer components with the attendant integration and qualification necessary.

The program under discussion used commercially available off-the-shelf components which are far less expensive than military oriented COTS or the much more expensive custom component solutions. In this case, the total quantity required was known at the outset of the program so it was cost effective to acquire enough of the commercial components to meet the entire lifetime requirement of the program.

## ESS TESTING

Environmental Stress Screening (ESS) is a process which exposes each manufactured article to a series of environmental stress tests. ESS testing can catch component manufacturing variances that may have undermined the operation of the system in the field. The three ESS tests were conducted in two complete cycles over two days. The first test is a five-minute test of random vibration on each axis. Then the unit under test (UUT) is placed in an altitude chamber, and a day's worth of pressure testing at various altitude temperature combinations is conducted. Finally, the UUT is placed in a controlled environment, and it is rotated through operating temperature cycles. While a design may be believed to be rugged on paper, passing a series of ESS tests provides an additional measure of confidence.

## WORKMANSHIP STANDARDS

One of the greatest challenges of using commercial products in extreme environments is ensuring they meet appropriate Workmanship Standards. Military products require adherence to the stricter IPC Class 3, while most commercial products meet the less-stringent Class 2. An exception needed to be made for the soldering on the commercial boards, but Atrenne's solder work met the IPC/EIA J-STD-001. As indicated above, ESS was successfully performed on each system to ensure that they would withstand the stresses of the specific application environment.





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## ATRENNE'S KEYS TO PROJECT SUCCESS

### Risk Assessment

Risk is mitigated by incorporating cross-functional assessments at every stage of the program. Risk assessment plans are initiated at the inception of the Atrenne Functional Project Management program, and critical risk elements to budget, schedule, design and manufacturing are identified and are tracked throughout

### Quality Procedures

The Atrenne process is a structured system that delivers fully-tested, reliable electro-mechanical solutions on-time and with world-class quality. Multi-stage design reviews include preliminary and critical reviews of product quality. In-house environmental stress screening (ESS) ensure that products will withstand the rigors of the environments and regulations they are designed to meet. External facilities test to confirm the system meets the following MIL-STD regulations and considerations.

### Certifications and Accreditations

- ITAR Registered
- AS 9100
- ISO 9001:2008
- J - STD - 001
- IPC / WHMA 620
- DFARS
- MIL-DTL - 5541



A gasket buffers two mating aluminum surfaces and preserves the hermetic seal.

## MARKET LEADER IN RUGGED, COTS CHASSIS AND BACKPLANES



ATR, Rackmount and Small Form Factor Enclosures

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## OTHER CHALLENGES

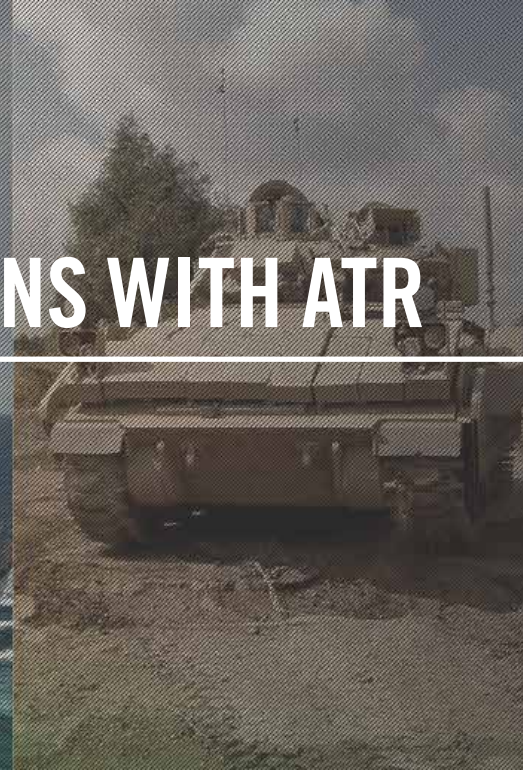
Additional challenges needing to be overcome in the design process included mating two aluminum surfaces to create a hermetically sealed chamber. We worked together with our partners to create a gasket that would act as a buffer for any mechanical tolerance differences or occlusions between the two fine aluminum surfaces. The gasket was made of a material that was viscous enough to overcome any impurities and yet still create a hermetically sealed environment. The sealed enclosure maintained an internal pressure of one atmosphere, simulating a lab environment at all times. This hermetically sealed chamber allowed for the use of boards with standard aluminum electrolytic capacitors, even though they had not been designed for use above 10,000 feet, by keeping them in a consistent lab environment.

After identifying and addressing these and other challenges, we successfully passed all of the military requirements placed on the program. A third party expert testing facility conducted the final verification on First Articles. After verification, the process includes a stage called Pre Ship reviews; an opportunity to discuss any last-minute issues, status of final test, QA inspection, and a review of chassis readiness for shipping. From the Pre Ship Review, an Integrated Master Schedule is developed, and once production is underway, regular risk assessment meetings are conducted.

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# OUR NAME BEGINS WITH ATR



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ATR Chassis Solution 99-193

- 1+ ATR Short, 7-slots, 6U
- Liquid-cooled chassis
- Conduction-cooled modules
- Operating temperature -40 to +60C
- Shock per MIL-STD-810
- Input 3-phase 400 Hz MIL-STD-704A, 750W
- Cooling for >150W per slot
- 1-2 Power Supply Slots



ATR Chassis Solution 688-00

- 1/2 ATR Tall Long, 14-slots, Hybrid 3U/6U
- Air-cooled chassis with air-to-air heat exchanger
- Air-cooled modules, 10 CFM
- Operating temperature 0 to 55C
- Three 3U 28 VDC-input pluggable power supplies, 1050W



ATR Chassis Solution 78-710

- 1+ ATR 10-slots 6U
- Liquid-cooled chassis / variety of cooling fluids
- Conduction-cooled modules
- Operating temperature -40 to +70C
- -1,500 to 60,000 ft. MSL
- 1-2 Power Supply Slots



ATR Chassis Solution 63-173

- 1+ ATR 13-slots, OpenVPX, 6U
- Liquid-cooled chassis/EGW
- Conduction-cooled modules
- Operating temperature -40 to +85C
- 0 to 50,000 ft. MSL
- Input 28 VDC, MIL-STD-704F
- 2700W power supply; can power and cool >200W per slot



ATR Chassis Solution 881-131

- 3/4 ATR Short, Small Form Factor 7-slots 3U
- Baseplate-cooled chassis
- Conduction-cooled modules
- Operating temperature -40 to 55C
- 0 to 28,000 ft. MSL
- Input 28 VDC MIL-STD-704F and MIL-STD-1275B, 450W

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## BENEFITS

The SWaP-C revolution is pervasive in the defense industry for good reason. Instead of long development schedules and high costs incurred by engineering ruggedized components, Atrenne was able to significantly cut costs and time to field by using our expertise to engineer a high-altitude FMV solution using COTS components. This enables the use of small form-factor boards, allows for more powerful equipment, and increases component availability. As well, our unique process allows for the possibility of applying these procedures to similar COTS equipment.

## SUMMARY

Atrenne was able to develop a successful solution in collaboration with our customer which met the needs for a high altitude FMV system built of COTS components. Our expertise allowed us to devise a solution to hermetically seal the system to maintain consistent internal atmospheric pressure, and incorporate thermal systems to heat and cool the components to maintain proper operating temperature. Atrenne thoroughly tested, vetted and reviewed every aspect of the system to meet SWaP-C, military and manufacturing standards. We were able to provide the solution when other vendors had failed, because of close communication with our customer/integrator and adherence to strict processes to meet the program's needs.

<sup>1</sup>The Airborne ISR Market 2013-2023: Intelligence, Surveillance & Reconnaissance Platforms & Technologies for Information Superiority

<sup>2</sup>Commercial-Off-the-Shelf (COTS): Doing It Right - Jacques S. Gansler, William Lucyshyn, 2008-15

## CALL TO ACTION

Contact Atrenne to discuss how a chassis solution can protect electronics from extreme environmental conditions.

## CONTACT INFORMATION

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- Ruggedization for air, land and sea
- 3U, 6U VPX, VME64x, VXS, CompactPCI and others
- 28 VDC, 48 VDC, 110 VAC, 220 VAC, ATX power supplies
- Power supply hold-up
- Lightning protection
- Design-build or build to print manufacturing
- Application-specific designs



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