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Understanding Your ATR Chassis Manufacturing Options

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No longer just for airborne applications, Air Transport Rack (ATR) chassis have become the most common type of enclosure for all types of deployed defense electronic systems. They have established a track record of offering the highest level of environmental protection while maintaining exceptional packaging density and thermal performance. The increasing number of ATR deployments has driven innovations in manufacturing technology, so that now there are distinct options for ATR chassis production.

Each manufacturing option has advantages as well as limitations. Making the best choice for any specific program requires analyzing those pluses and deltas in the context of the program's unique requirements. Atrenne Computing Solutions has delivery capability and experience with all three options. Using that experience, this paper will examine the benefits and design trade-offs of each option, so that program managers and executives can make an informed decision on which will work best for their situation.

ATR Chassis are Rugged and Standards-Based

Optimized for field deployments, ATR chassis are designed to withstand a variety of adverse environmental variables such as shock, vibration, temperature, electromagnetic interference, humidity, fungi, fluid susceptibility, salt fog, acoustic noise, and altitude extremes. Each application has its own set of tough environmental factors that must be considered.

Cooling for an ATR chassis can be implemented by natural convection or forced air conduction (external fan); the latter method has more thermal capacity and is the most common method for today's deployments.

Forced air conduction first uses conduction cooling of payload modules via wedgelocks that are in contact with the enclosure side walls, transferring heat to those side walls. Within the sidewalls are plenums (air-moving chambers); exhaust fans pull outside air overheat dissipation fins in the plenums, then exhaust it at the rear of the chassis. This approach, often called 'Air Over-Conduction', efficiently removes elevated levels of thermal energy from the system without exposing critical electronics to dust, smoke, or corrosive conditions of extreme environments.

Natural Convection Cooled ATR Enclosure

Forced Air Cooled ATR Enclosure

ATR chassis are defined by the ARINC 404A and ARINC 600 standards. They come in a wide range of sizes, starting with a baseline 'full ATR' width of 10.12", then going down to ½ and ¼ ATR and up to 1 ½ ATR. There are two common length options, Short ATR (12.62") and Long ATR (19.52"), and two common height options, Regular (7.62") and Tall (10.62"). This standards-based size flexibility means that program managers can select an ATR chassis that fits their deployment requirements without the added cost and schedule impact of a custom system.

ATR chassis can also be designed to comply with several other industry standards. Below is a list of standards adhered to by various deployed Atrenne ATR chassis.

GOVERNMENT DOCUMENTS	DESCRIPTION
MIL-A-8421	Air Transportability Requirements
MIL-HDBK-454	General Guidelines for Electronic Equipment
MIL-STD-1472	Human Engineering, DOD Design Criteria Standard
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-810	Department of Defense Test Methods for Environmental Engineering Considerations and Laboratory Tests
NON-GOVERNMENT DOCUMENTS	**DESCRIPTION**
RTCA/DO-160G	Environmental Conditions and Test Procedures for Airborne Equipment
ANSI/VITA 48	Mechanical Specification for Microcomputers Using Ruggedized Enhanced Design Implementation (REDI)
ANSI/VITA 48.2	Mechanical Specification for Microcomputers Using REDI Conduction Cooling Applied to VITA VPX
ANSI/VITA 62	Modular Power Supply Standard
ANSI/VITA 65	OpenVPX™ System Specification
ARINC-404	Air Transport Equipment Cases and Racking
SOSA™	SOSA™ Reference Architecture, Edition 1.0

The three currently available ATR manufacturing processes are:

- Aluminum Brazed (Dipped or Vacuum)
- Aluminum Bolted and Bonded Seam
- Aluminum 3D Printed (Additive Manufacturing)

Aluminum Brazed (Dipped or Vacuum)

Aluminum brazed ATR enclosures are a proven technology, currently deployed in a vast range of conditions and environments. The brazement can be fabricated by a either the dipped or the vacuum brazed methods. However, vacuum brazing is limited to flat, stacked horizontal surfaces, so the required pressure can be applied. In consequence, most of Atrenne's brazed ATR enclosures are dip brazed.

Brazed ATR chassis are rugged and can handle almost any set of environmental conditions. However, the brazement process involves long lead times, usually estimated at 26+ weeks. To mitigate the impact of that lead time on customer delivery, chassis are often released for brazement while final system design details are still being worked out. This approach does introduce risk, because sometimes final design alterations require changes to the finished brazement. That rework will affect both cost and lead time and may also require specialty tooling. In a worstcase scenario, where the brazement cannot be reworked, a completely new brazement process is required, adding a new 26+ weeks to the project.

In summary, the aluminum brazed manufacturing option is reliable and well understood but comes with a significant schedule impact; reducing that expected schedule impact involves accepting some risk.

Bolted and Bonded

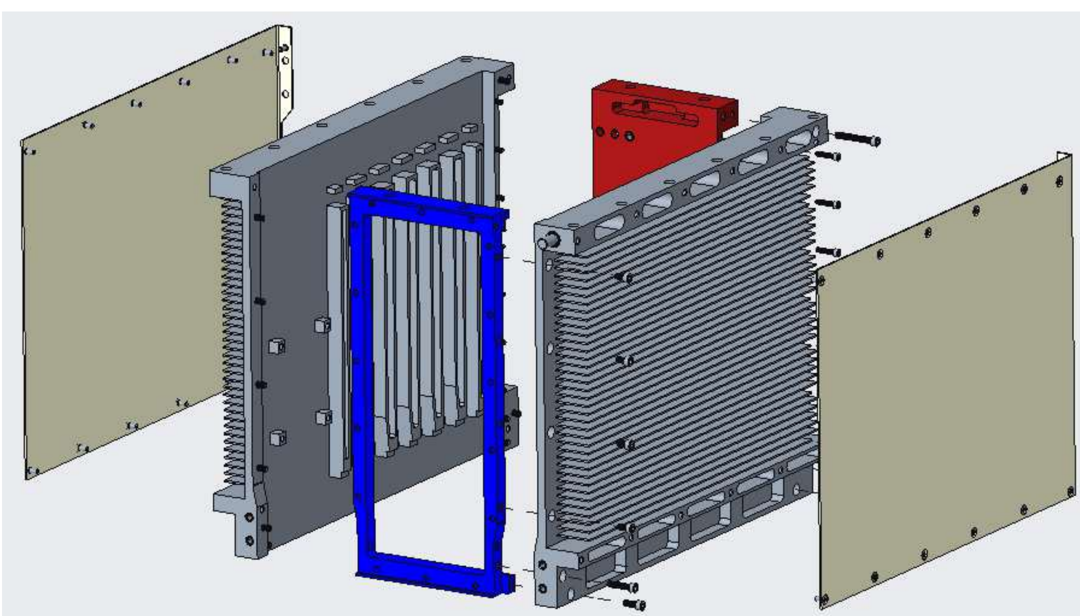
Atrenne has developed and perfected an innovative Bolted and Bonded chassis manufacturing technology that significantly cuts both costs and lead times. In this unique approach to joining rugged chassis components, connecting bolts absorb shock and vibration while a thermally conductive film adhesive bonds the seams between component segments.

Previous industry attempts at Bolted and Bonded chassis construction have used silver conductive epoxy adhesives, with highly inconsistent results. Atrenne's unique adhesive is applied with high-precision techniques to create bonds that are both thermally and electrically conductive, as well as uniformly strong.

Atrenne's innovative film technique is not only great for heat transfer, but it also forms a watertight bond that protects electronic components within the chassis. In addition, its electrically conductive characteristic simplifies system grounding.

Bolted and Bonded chassis are fabricated entirely in house by Atrenne, drastically cutting lead times relative to the brazement approach. Given the short lead time, fabrication can be scheduled after final design approval, greatly reducing the risk of rework. If changes are needed after testing, the bolted fasteners can be removed from the enclosure, the affected part(s) modified, and then reassembled with bolts and new adhesive. Special tooling is not usually required and schedule impact is small.

Both experience with real world chassis, and extensive simulations, demonstrate that the thermal characteristics of Bolted and Bonded chassis mirror those of brazed chassis. Manufacturing costs are cut, while lead times and related schedule risks are greatly reduced.



A Bolted and Bonded ATR Chassis Schematic

3D Printed (a.k.a., 3D Additive Manufacturing)

At Atrenne, our focus on optimized defense electronics customization led us to develop a unique and innovative capability, aluminum alloy 3D printed chassis. This cutting-edge process creates real, deployable enclosures, not mock-ups. It means you can demonstrate to your customer a new design in weeks, not months.

Also referred to as Metal Additive Manufacturing (MAM), metal 3D printing gives mechanical engineers the freedom to create complex parts without the design constraints of traditional subtractive manufacturing methods. Most of today's ATR chassis are made from aluminum alloys, delivering an outstanding combination of structural strength, light weight, and thermal conductivity. Metal 3D printing can also use aluminum alloys, providing the same set of advantages for system chassis.

Metal 3D printing works by addressing very thin layers of metal powder with a laser beam that fuses the particles to form a solid monolithic structure. Each layer of metal power is approximately 2 thousandths of an inch thick, or half the thickness of a human hair. The laser fuses only the particles that define the design's cross section for that layer, then another layer of powder is put down and another defined cross section fused.

This automated process, moving layer by layer, is used to complete a chassis and results in a single piece that matches the CAD model input with extreme precision. Shapes and contours in the design are not limited by the capabilities of a CNC machining tool and there are literally no joints between sections, because there are no separate sections.

Aluminum alloy 3D printed chassis deliver multiple advantages; the most obvious advantage is a significantly reduced system development schedule. After completion of the CAD design, a new, custom-designed chassis can be created using 3D printing in about six weeks.

The fast development time means that a prime contractor can get something tangible in front of a customer during a project's initial stages. This, of course, builds confidence, but it also allows a physical fit check to ensure that the chassis design is actually compatible with the platform in terms of dimensions, cabling connections, etc. Constructed from aluminum alloy, the same chassis used for the fit check can also be used for system testing, after integration of the backplane, electronics, and power supplies.

One of the most exciting characteristics of 3D printing is that chassis designers can implement innovative material shapes. Lattice structures are the prime example, delivering strength with greatly reduced weight, as well as outstanding heat dissipation based on substantial increases in exposed surface area.

A disadvantage of the 3D metal printing process is that it is more costly than the Traditional Brazement or Bolted and Bonded approaches. As such, it is most suitable for prototypes, one-off custom parts, and low volume production runs. Secondary processes are often required, such as stress relieving and CNC machining of surfaces for mating components.

This 3D Printed ATR Chassis is a one-piece unit.

Further, it is important to understand that a chassis must be designed specifically for 3D printing because of printing process limitations. A chassis designed for another fabrication process will need adjustments to meet 3D printing requirements.

Unfortunately, it is not possible to finish a 3D printed enclosure with chromate in accordance with MIL-DTL-5541, as the process turns the chassis black and leaves a residue. The chassis requires anodization or electroless nickel plating; nickel plating is recommended when conductivity is required.

Clearly the design trades of 3D metal printing must be carefully evaluated for each specific project, balancing greatly compressed delivery time and extreme design flexibility against increased cost and unique process issues.

Discuss your Program's Needs with our Experts

Atrenne continues to deliver ATR chassis using all three manufacturing methods, supporting standardized, cost effective solutions for SOSA™, VPX, VME, VME64x, cPCI, and VXS based applications, in sizes from ¼ to 1½ formats per ARINC 404A, ARINC 600 specifications. These ATRs are used for a wide range of rugged airborne, naval, and ground mobile deployments.

Our system design experts would welcome the opportunity to discuss your program's unique requirements and help you select both the chassis type and the manufacturing process that will best meet those requirements.

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