**High-Density Computing Systems in Surveillance and Communication Applications**

By

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## Introduction – Boeing RC135V/W Mission Overview

Correct and timely information about enemy location, strength and attack plans is just as important today as it was in ancient times.  The only difference is that the weapon technology of today enables the opposing forces to largely stay out of sight of each other. This makes the ability to deliver accurate information as essential to a successful outcome as the firepower available to each opposing side.  Long gone are the days when battlefield surveillance was only available by sending out scouting parties to climb the tallest trees or cliffs to gather the information needed by the battlefield commanders.  The scouts of yesterday have been largely replaced by flying technology platforms like modern surveillance aircraft and spy satellites.  These flying technology platforms provide not only location information, but in the case of surveillance aircraft also supply the near real-time situational analysis needed to make sense of the huge quantities of data captured by today's technology.

Surveillance aircraft like the Boeing RC-135V/W or RIVET JOINT are packed full of the necessary technology to serve as the eyes, ears and voice of personnel engaged with hostile forces.  The "RJ" or Hogs" are aircraft platforms that have been around since 1959 and used extensively in various conflicts around the globe.  The term "Hogs" comes from the aircraft's extended hog-like nose and side protrusions that resemble "hog cheeks".  The hog nose and hog cheeks house multiple antenna arrays and other communication gear.  The RJ has gone through many iterations and upgrades since being introduced.  These changes keep the plane up to date technologically speaking and enable it to remain a valuable member of the armed forces.  The RC-135V/W in its latest configuration is a cost-efficient piece of military hardware that senses, analyzes, locates and records signals throughout the electromagnetic spectrum.  On-board intelligence specialists, technicians, flight crew and a sophisticated array of computer and communication equipment are used to accomplish the aircraft's mission.

**RC-135V/W**

**In-flight Workstation**

The seventeen "Hogs" currently in service rotate through a regularly scheduled upgrade program that maintains and enhances the aircraft's tactical advantages.  Updating the surveillance systems to the latest available Mil-COTS single board computer technology as well as refurbishing the flight systems of the plane are the main objectives of the upgrade program.  A plane operates seven to ten years between upgrades.  A typical RC-135V/W upgrade configuration requires 65 to 75; 19" rackmount computer systems to satisfy the armed forces needs for accurate battlefield surveillance and secure communications.

## The Embedded Computer Design Challenges

Now that you know the basic mission and upgrade requirements of the aircraft, lets' take a look at some of the system design challenges of the RC135-V/W upgrade program. One of the first design questions is; "How are we going to provide the immense computational horsepower needed to meet the aircraft's mission objectives in a highly space, weight and power (i.e. SWaP) constrained environment?" The computer systems must also be flexible enough to handle the multiple system configurations used in the aircraft. The computers have to last a long time and have a stable system configuration to meet the aircraft's deployment and refurbishment schedules. The military end user needs Mil-COTS (**M**ilitary **C**ommercial **O**ff **T**he **S**helf) technology used whenever possible. While this appears to be a daunting design challenge, let's see how Trenton worked with the OEM and end user to solve the customer's application challenges with embedded, multi-core, Intel® Architecture processors, Trenton's PICMG® 1.3 single board computers and multi-segment, passive backplanes.

## High-Density / Cluster Computing System Design – The Chassis

In any aircraft design or system upgrade project, total system component weights are of critical importance. For surveillance aircraft, this weight problem has an exponential cumulative effect on the cost of operating the aircraft. Depending on the specific RC-135V/W configuration, the plane can have a crew of up to 34 individuals including flight crew with around twenty-seven or so of these individuals working with the computer systems. Next you add in the computer chassis, the equipment racks needed to secure the chassis, the display monitors, the worktables, chairs for the personnel and all of the other hardware needed to perform the mission and you get the picture: weight and space are at a premium in surveillance aircraft. A significant corollary to this basic military aircraft design truism is that extra weight cost money and time in terms of added fuel costs and increased mid-air refueling time.

The OEM and Trenton addressed this weight issue by coming up with a shallow depth chassis made out of lightweight aluminum. Figure 1 shows an expanded view of one of the chassis platforms used on the RC-135V/W.


**Figure 1 – Trenton TRC5000**

## **High-Density Computing System Design – The Chassis** (continued)

The most common 19" rackmount chassis used on the aircraft has a chassis depth of 45.72cm (18") and a 5U chassis height. This system is called the Trenton TRC5000. Some applications require a 4U chassis height with a resultant chassis depth of 58.42cm or 23" (Trenton TRC4002). A few mission stations require a compact 2U chassis design with one single board computer and a butterfly backplane (Trenton TRC2003). Other high-density computer chassis design elements include individual single board computer segment power control, quick access storage drives, corrosion resistant metalwork, a high-performance cooling system and armored cable sleeves for vibration protection.

Figure 2 illustrates the subtle, but critical manufacturing techniques that go into building all Trenton rackmount computers.

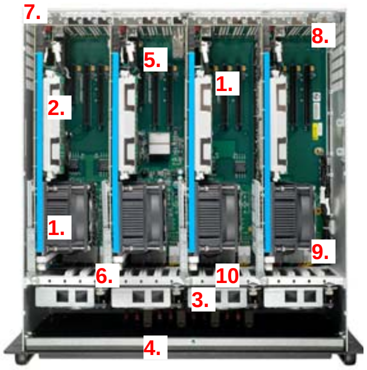
**1. Stable Technology**
- 7-10 year availability
- 5-year board warranty

**2. Secured Memory Seating**
- Locked-down DIMMs
- Better vibration performance

**3. High CFM/Hot-Swap Fans**
- Ensures proper cooling
- Reduces downtime

**4. Tool-Less Filter Access**
- Eases serviceability
- Limits internal access

**5. Shrink-Wrapped ID Labels**
- Simplifies maintenance
- Eliminates errors




**6. SHB Hold Down Bracket**
- Increased vibration stability
- Enhances Longevity

**7. Rugged Chassis**
- Lightweight aluminum
- Provides strength & stability

**8. Rear & Side-Vented Enclosure Slots**
- Ensures proper cooling
- Enhances reliability

**9. Protective Cable Sleeves**
- Prevents vibration damage
- Enables efficient cabling

**10. Grommet Component Edges**
- Ends metal-to-cable vibration
- Prevents wire damage

**Figure 2**

Note: If you are reading this on-line, and embedded Hyperlink in the Figure 2 chassis photo will take you to a Trenton Systems manufacturing video for more details on the system's assembly techniques and design advantages.

Each high-density /cluster computing system has a multi-segment PICMG 1.3 backplane that enables multiple single board computers to function in a single chassis. Each segment on a backplane also supports a variety of option cards used for communications, video, sound, data storage, etc. Separate HDD storage arrays are located in system component racks along with the 5U rackmount computers. Each backplane segment is a computer unto itself and as we shall see with Intel® Virtualization Technology, each single board computer can be further sub-divided into running multiple applications on a single SBC.

## High-Density Computing System Design – Single Board Computers

One of the many advantages to a PICMG 1.3 single board computer design is the ability to place a self-contained SBC in a passive backplane and group it with industry standard Mil-COTS plug-in option cards and/or other single board computers. This inherent design advantage allows you to mix and match single board computer capabilities based on the needs of the application. Figure 3 shows the two types of Trenton single board computers that are used in the rackmount systems built for the RC-135V/W aircraft and they are the Trenton TQ9 single board computer and the Trenton JXT6966 single board computer. Both SBCs use quad-core processor technology featuring Intel® Virtualization Technology.

**Trenton TQ9**

**Trenton JXT6966**

**Figure 3**

Implementing Intel® Virtualization Technology allows a system designer to have each processor core run a specific application. A Trenton TRC5000 chassis with four, dual-processor SBCs with quad-core Intel® Processors and Intel® Virtualization Technology makes it possible to run up to 32 different applications; i.e. one application for each processor core in a single 5U chassis. This means that one 5U TRC5000 rackmount computer can take the place of sixteen 1U dual processor motherboard systems. Using a single 5U enclosure instead of sixteen 1U enclosures reduces rack space by 19.25" (48.90cm) for a total unit space savings of nearly 70%.

Remember that an aircraft can have up to seventy-five systems, so this space savings is repeated many times throughout the plane. The space savings supplied by the Trenton high-density cluster computer solution also comes with a cumulative weight savings advantage because the solution requires fewer cables, enclosures and power supplies.

So far, we have only briefly outlined the features of the single board computers. In the following sections, we take a closer look at the technologies in the two SBCs used in this airborne surveillance aircraft application: the Trenton TQ9 single board computer and the Trenton JXT6966 single board computer.

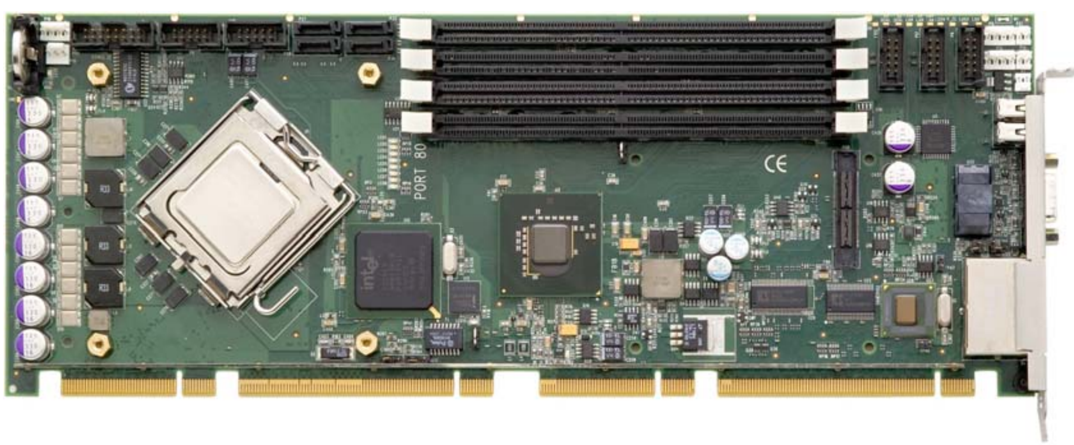
**Trenton TQ9 Single Board Computer (SBC)**

The TQ9 is a graphics-class PICMG 1.3 single board computer meaning that the SBC supports a PCI Express® edge connector configuration of one x16 and one x4 PCIe electrical link. The x4 PCIe link may be used on a backplane as four individual x1 PCIe links. Some systems on the RC-135-V/W need a high-performance video graphics card. The Trenton TQ9 supports the x16 PCIe electrical link that is a common edge card connector interface on many high-end video and graphics cards.

The Intel® Core™ 2 Processor Q9400 and the Intel® Q35 Express Chipset is used in the TQ9 configurations on the aircraft. The processor features a quad-core design, a 1333MHz front side bus and Intel® Virtualization Technology. Virtualization enables multiple operating systems to run on the TQ9, which in turn allows the end user to run multiple applications on the same SBC. Multiple TQ9 SBCs running multiple applications display the application's result information to different monitors for the intelligence specialists.

Other TQ9 features include:

- Four, DDR2-800 sockets support up to 8GB of system memory
- Four SATA II 300 interfaces with RAID support
- On-board audio support
- On-board video support
- Eight USB 2.0 interfaces
- Supports I/O expansion board including an optional TPM 1.2 module



**Trenton TQ9 Single Board Computer**

**Trenton JXT6966 Single board computer (SBC)**

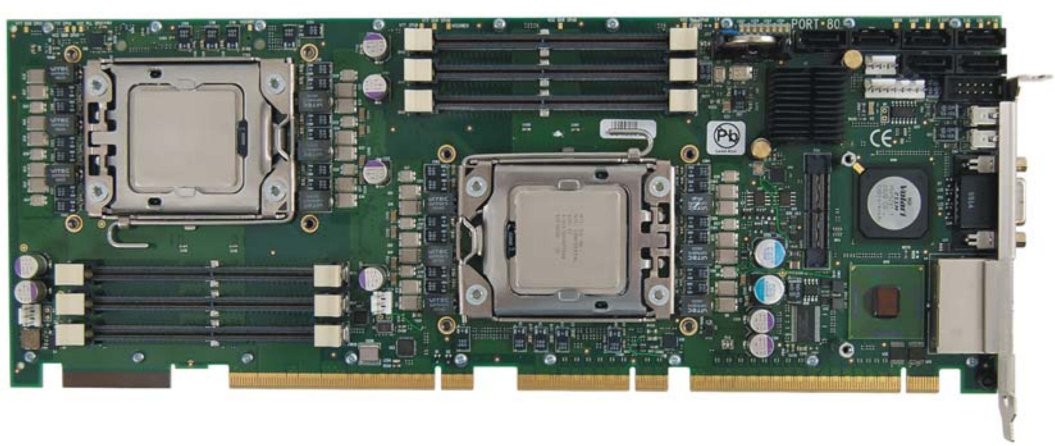
The JXT6966 is a dual processor, combo-class PICMG 1.3 single board computer. Multiple x4 PCI Express 2.0 electrical links are supported directly out of the first CPU on the SBC. The PCIe routed to the SBC's edge connectors automatically combine into either a graphics-class (1 – x16 and 1 – x4) or a server-class (2 – x8 and 1 – x4) link combination depending on the type of PICMG 1.3 backplane used in a system application. The second CPU on the board provides additional PCIe 2.0 electrical links to support PCI Express expansion links that provide added system bandwidth capabilities. Systems using the JXT6966 are computers in the aircraft that are processing the heaviest load of data and the most complex situational analysis software.

Both processors on the JXT6966 are extended-life, quad-core processors. Specifically the JXT6966 configurations on the plane use the Quad-Core Intel® Xeon® C5500 series or processors (i.e. Jasper Forest) and the Intel® 3420 Platform Controller Hub or PCH. Both processors on the JXT6966 communicate directly to the DDR3-1333 system memory modules, the PCI Express cards and devices in the system and the board's PCH. This Jasper Forest processor capability enables faster system performance and data throughput. Intel® Virtualization Technology (Intel® VT-x2 and Intel® VT-d2) is also supported on this Trenton JXT6966 SBC configuration.

Other JXT6966 features include:

- Six, DDR3-1333 Mini-DIMM sockets support up to 48GB of system memory
- Six SATA II 300 interfaces with RAID support
- On-board WUXGA video support
- Eight USB 2.0 interfaces
- Three 10/100/1000Base-T Ethernet interfaces
- Supports PCI Express 2.0 link expansion

The long-life product support provided by the Intel® Embedded and Communication Group allows the OEM to utilize Trenton Systems hardware to meet the stability and longevity requirements of the RIVET JOINT upgrade program. Trenton designs in other extended life components to ensure that the completed systems meet and exceed the deployment cycle requirements for the aircraft.




**Trenton JXT6966 Single Board Computer**

## Cluster Computing System Design – Other Option Cards

We previously talked about the need for flexibility in the various computer systems used on the RC-135V/W aircraft. The single board computer and backplane system architecture supports this major design requirement by providing backplanes with multiple option card slot interface configurations. The backplanes in the systems support a variety of option cards such as four-channel Ethernet communication cards, iSCSI option cards that interface to data storage boxes and sound cards. Not all systems get the same option card configuration, but all systems are flexible enough to be re-configured and re-deployed as necessary to meet any special mission requirements of a specific aircraft.

## Cluster Computing System Design – Multi-Segment Backplane

A frequently overlooked and often times under-appreciated component of an embedded computing system design is the backplane. To use a biology analogy, the backplane functions as the circulatory system of an embedded computer. The backplane's primary function is to maintain the flow of the system's lifeblood, i.e. its processing data. Today's higher bandwidth card-to-card interfaces such as a PCI Express demand robust backplane designs in order to maintain optimum system throughput performance.

The most common backplane used in the systems is the four-segment Trenton BP4FS6890 backplane. This PICMG 1.3 backplane is a key design element because it allows Trenton to install up to four single board computers and the OEM in turn can install a variety of option cards in a single 19" rackmount chassis. This system design feature, in combination with Intel® Virtualization Technology allows us to save rack space by enabling up to four single board computers to run multiple independent applications or function together as a high-density computer cluster.

Figure 4 illustrates the possible configurations for the [Trenton BP4FS6890 backplane](#).

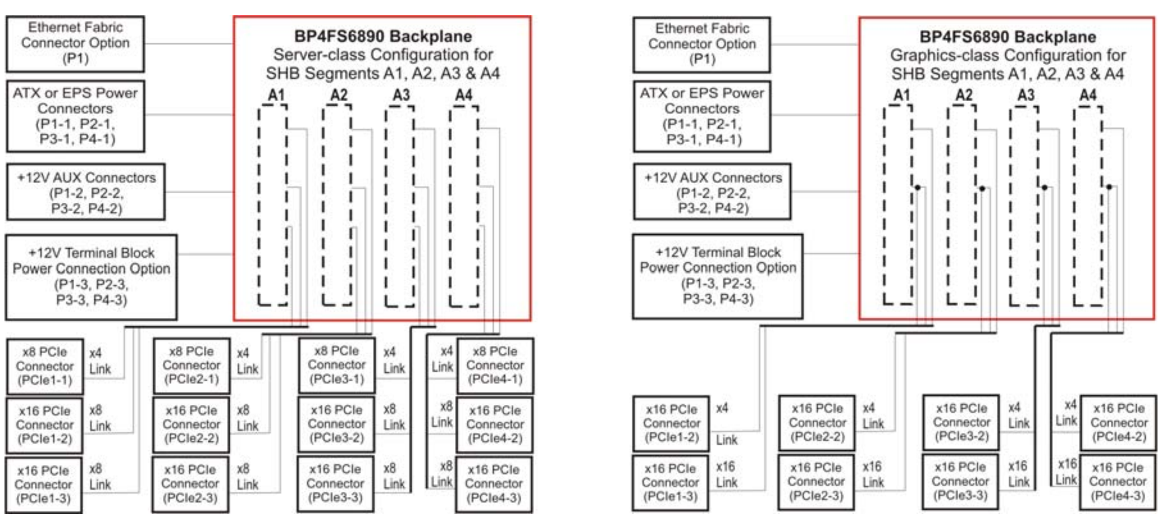



**Figure 4**

Notice that the Trenton BP4FS6890 supports all PCI Express option cards. Other backplane configurations used in the aircraft support different option card combinations and card interfaces including PCI and PCI-X.

## Cluster Computing System Design – Summary & Conclusion

The unique space requirements we just talked about in the RC-135V/W aircraft; while challenging, are certainly not unique. Equipment space constraints also exist in medical diagnostic systems, telecom, industrial automation and any other application where you want to save space. Weight limitations may not be as demanding unless you plan on flying around the CAT scan system, but lighter weight equipment designs sure make the system engineer popular with the installation and maintenance technicians.

Trenton single board computers and multi-segment backplanes bring the same space and efficiency benefits as seen in the RC-135V/W aircraft to a wide variety of embedded computing applications. Many applications need to run different applications on a single platform and single board computers and backplanes have long made this possible. This basic architecture design advantage is now coupled with the Intel® Virtualization Technology. This potent combination gives system designers the ability to leverage the benefit of cluster computing across a broad range of industry applications.

To learn more about high density cluster computing or other Trenton computer systems and board-level products contact us at:

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