

RAD6000 Radiation Hardened 32-Bit Processor



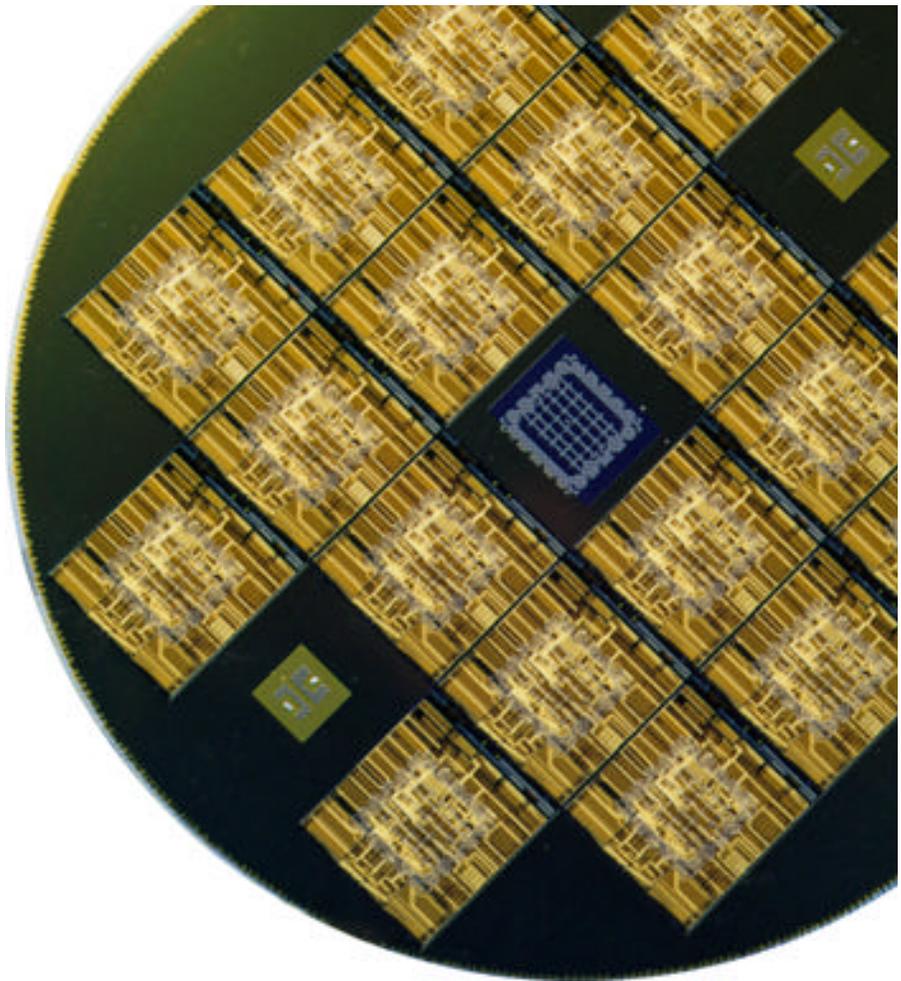
Radiation Hardened RAD6000

The Lockheed Martin Federal Systems RAD6000 is a low cost, high performance 32-bit Reduced Instruction Set Computer (RISC) that combines the popular and proven PowerArchitecture™ of the IBM RISC System/6000® workstation with radiation hardened Very High Speed Integrated Circuit (VHSIC) technology to provide powerful and flexible solutions for avionics, launch, and space applications.

Heritage and Vision

Proven architecture, design and software heritage from the commercial market establishes the RAD6000 with a performance that is unrivaled in space processors. The RAD6000 is a direct transfer of the IBM RISC System/6000 single chip CPU to the Lockheed Martin radiation hardened process. SEU hardening has been applied to all storage elements in the RAD6000 including latches, registers and RAMs. Being gate-for-gate identical with its commercial counterpart, the RAD6000 uses many commercial software products without modification, including the industry-leading V_xWorks, significantly reducing application software development costs and risk. Workstations may be used as breadboards for early software development.

The RAD6000's excellent heritage is equally complemented by its forward legacy! Being software and hardware compatible with the PowerPC™ family of micro-processors, the RAD6000's future includes multiple rad-hard PowerPC versions.



RAD6000 Key Features

- 35 MIPS at 33 MHz
- Radiation Hardened 32-bit RISC Super Scalar Single Chip CPU
- 8K Byte Internal Cache
- Simplex or Dual Lock-step Compare CPU Operations
- Low Power 3.3 Volt Operation
- 72-bit (64 Data, 8 ECC) Memory Bus
- Variable Power/Performance
- Independent Fixed and Floating Point Units with Concurrent Operation

Radiation Hardness Levels

- Total Dose: 2×10^6 rads(Si)
- Prompt Dose Upset: 1×10^9 rads(Si)/sec
- Survivability: 1×10^{12} rads(Si)/sec
- Single Event Upset: 1×10^{-10} Upsets/Bit-Day
- Neutron Fluence: 1×10^{14} N/cm²
- Device Latchup: Immune

Proven Technology, No Risk Migration

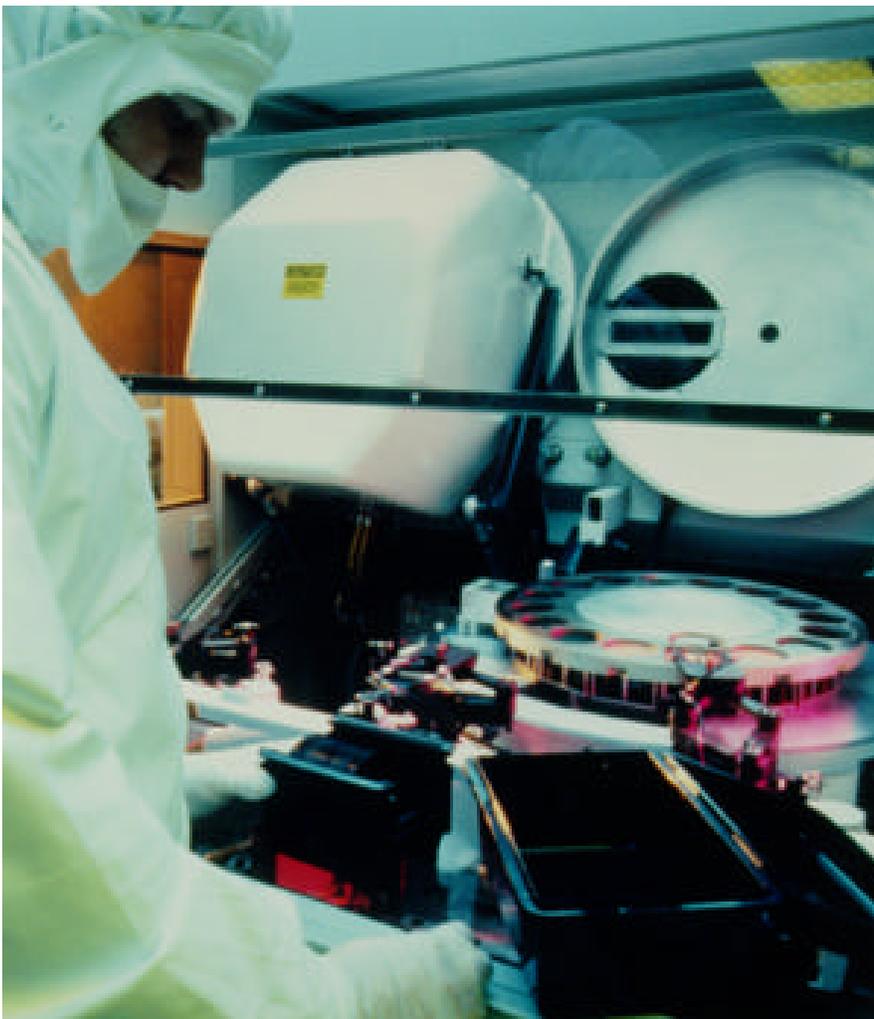
Lockheed Martin's proven radiation hardened Complementary Metal Oxide Semiconductor (CMOS) process developed in Manassas is used to fabricate the RAD6000. This process is directly compatible with that used by IBM in the fabrication of the IBM RISC System/6000 workstation. Masks compatible with the radiation hardened CMOS process are generated directly from the commercial graphic design resulting in a complete gate-for-gate duplication. The use of existing chip designs, validated architectures, and existing and thoroughly tested software virtually eliminate CPU risk.

- NO software translators
- NO "subsets"
- NO ". . .-like" designs
- NO "within the envelope"



Radiation Testing

Lockheed Martin Federal Systems VLSI Clean Room



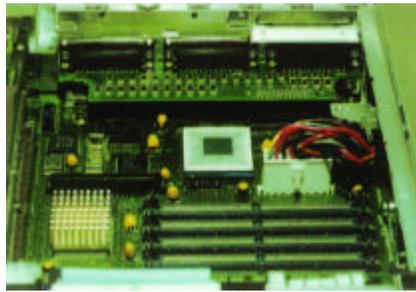
The radiation hardened single chip RISC System/6000 CPU is in full production at the Manassas radiation hardened semiconductor fabrication facility. The radiation hardened CPU version, (RAD6000), was validated by performing the identical CPU operations of a commercial CPU in a RISC System/6000 workstation. Total dose and SEU testing further validated the migration as successful. The flight qualified RAD6000s are fabricated using our fully scaled 0.5 micron radiation hardened QML-qualified process.

Lockheed Martin also offers unique high-density packaging for applications requiring low volume, including custom MCM solutions. Advantages include improved density, higher reliability, and lower overall cost.

*Masks . . .
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RAD6000 Single Board Computers

Lockheed Martin RAD6000 single board computers combine commercial standards with unique radiation hardened technology and packaging to meet the specific requirements of avionic, launch, and space applications. The RAD6000 single board computers include support functions to control local memory, and provides standard and custom I/O interfaces including ASCM Module Bus and TM Bus, VME, 1553, HSS, and IEEE 1394 "FireWire." Lockheed Martin has implemented support functions in both FPGAs and ASICs. The ASIC version supports simplex and lockstep CPUs and the I/O bus is the Peripheral Component Interconnect (PCI) bus, a commercial industry standard. The PCI is to application interface development as the IBM workstation is to software development. Application I/O may be developed independent of the core CPU.



RAD6000-SC Demonstrated in Workstation

The FPGA implementation has reduced function and a simpler I/O with less interface protocol. Both designs are fully static, permitting variable speed operation under software control to match power and performance requirements. The memory interface includes error correction logic.

The single support ASIC provides memory control for either Static Random Access Memory (SRAM), PROM, and EEPROM (max: 128 MBytes), as well as SUROM. The PCI bus is the standard interface for external I/O operations. Up to five masters and two slaves may access

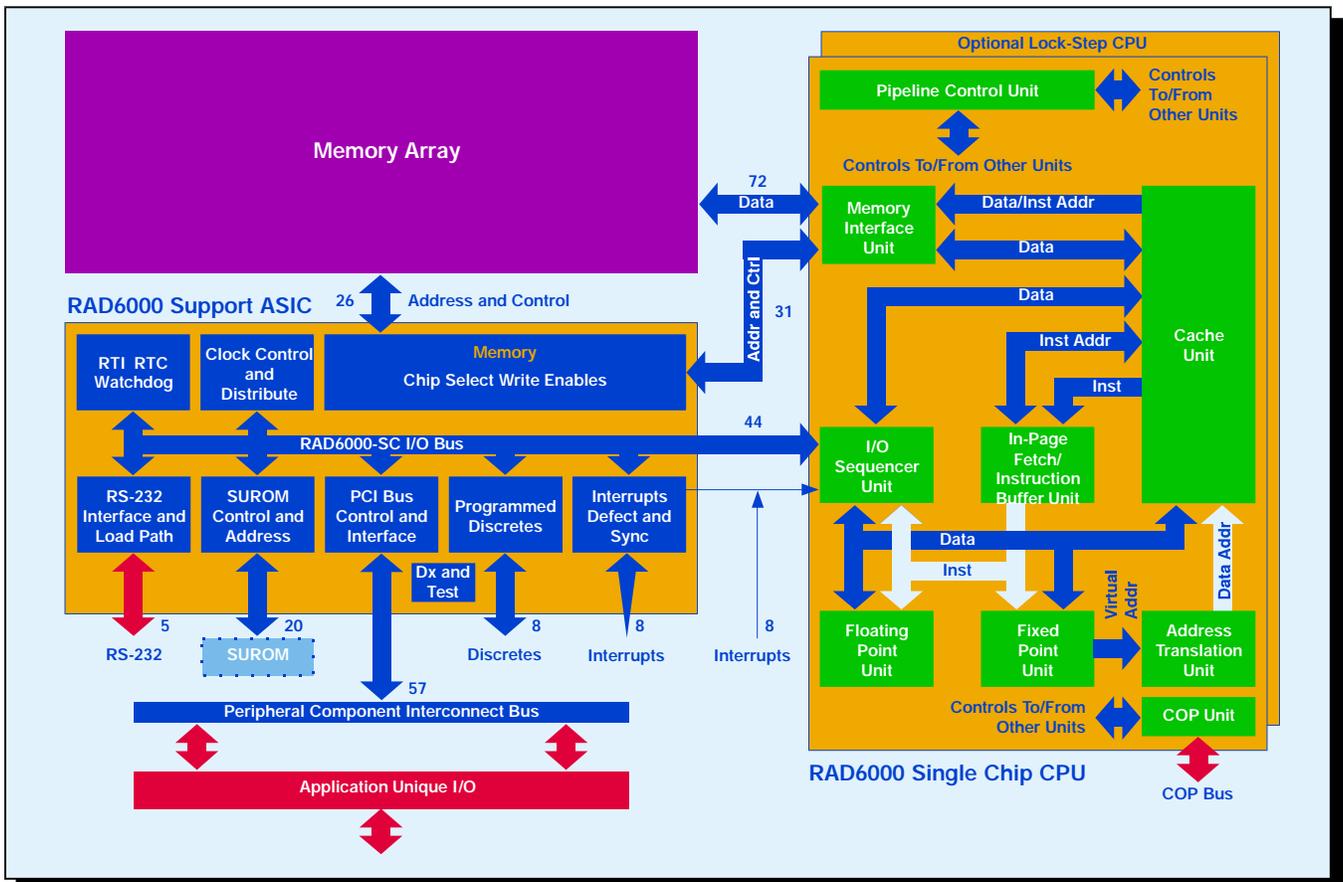
RAD6000 is configurable as a simplex or lock-step CPU.

the bus allowing for Direct Memory Access (DMA) and I/O intensive operations external to the CPU. Programmable interrupts and discretes and a host interface are provided. Start-up ROM addressing (up to 512 KB) is via the support chip.

The FPGA support chips provide memory control of up to 128 MByte DRAM and provides a system I/O bus for application specific I/Os and SUROM.

Lockheed Martin has implemented all RAD6000 support and I/O interface functions in robust, rad-hard, low power ASIC designs.

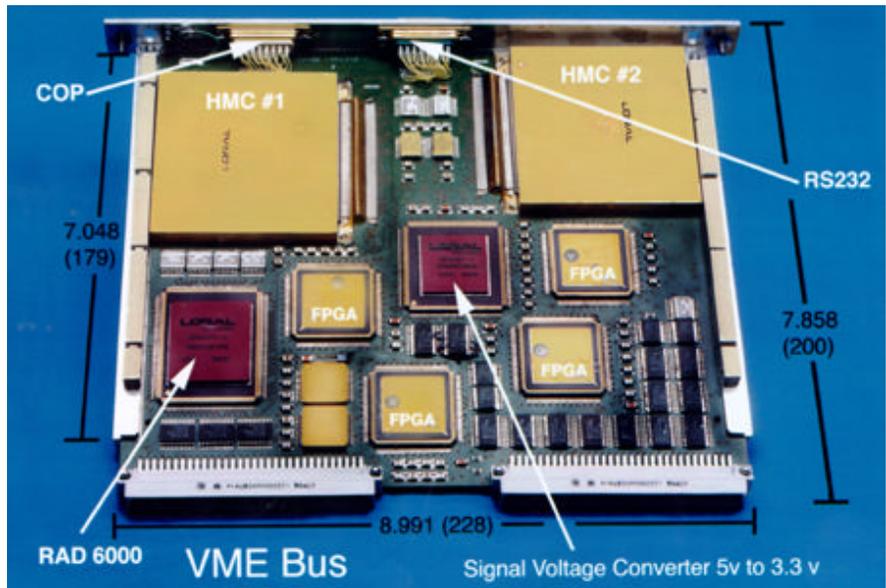
RAD6000 single board computers include CPU, memory, and interface support.



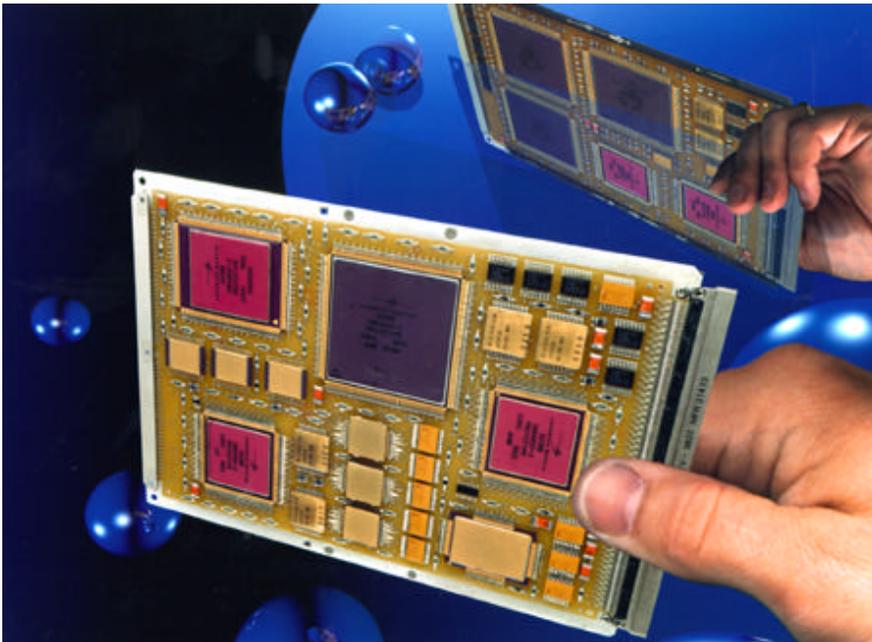
RAD6000 Applications

The versatility of the RAD6000 is further demonstrated in the variety of current application configurations available and under development. Packaging options, architecture variations, memory configurations and I/O selections such as those found in

- JPL Mars Pathfinder and MSP Flight Computers (FPGA Implementation)
- Advanced Technology Insertion Module-based 32-bit Single Board Computers



RAD6000 Mars Pathfinder Flight Computer



RAD6000 ATIM Single Board Computer

- Solid State Recorder Applications Demonstrate the flexibility of the RAD6000 architectures. Performance ranges from below 3 MIPS to above 35 MIPS. Fault tolerance is architected into every board.

The ATIM single board computer supports an 8 MByte local SRAM memory, MIL-STD-1553 interface, 4 HSS interfaces, and the advanced ASCM Module Bus. Fault management includes Availability Management System as part of the operating system and optional lock-step CPU operation. Performance is scalable to 35 MIPS.

The Mars Pathfinder computer has a 128 MByte DRAM memory, a VME interface, and a RS232 port.

Lockheed Martin RAD6000 boards support up to 9 MB local SRAM, 1553, QHSS, 1394 and ASCM module bus.

Processor Configuration Information

	ATIM Single Board Computer	Mars Pathfinder	Mars Surveyor	Gravity Probe B	SMEX-Lite
Performance	Variable to 35 MIPS	Variable to 22 MIPS	Variable to 22 MIPS	Variable to 18 MIPS	Variable to 27 MIPS
Frequency	Variable to 33 MHz	Variable to 20 MHz	Variable to 20 MHz	Variable to 16.4 MHz	Variable to 25 MHz
Power (Maximum)	13 Watts at 33 MHz	10 Watts at 20 MHz	20 Watts at 20 MHz	13 Watts at 16.4 MHz	9 Watts at 25 MHz
Power (Low)	5 Watts at 4 MHz	2.5 Watts at 2.5 MHz	5 Watts at 2.5 MHz	3 Watts at 2 MHz	2.5 Watts at 3.1MHz
Memory	8 MByte SRAM	128 MByte DRAM	128 MByte DRAM	4 MByte SRAM	4 MByte SRAM
EEPROM	0.25 MByte	None	3 MByte	0.25 Mbyte	1 MByte
Mass	<0.8 Kg	<0.9 Kg	<1.2 Kg	<1.0 Kg	<0.6 Kg
Size	SEM ES	6U VME + 2"	6U VME	7" x 7"	Estimated 6" x 8"
Interfaces	AMB, 1553, QHSS, RS232, TM, 1394	VME, RS232	VME, RS232	Serial, Parallel, 1553/1773, HSS, RS232	PCI, 1553, QHSS
Support Functions	ASIC	FPGA	FPGA	ASIC	ASIC

Software Benefits

Direct implementation of the workstation CPU architecture into the RAD6000 approach significantly benefits software development through direct applicability of commercially available tools and extensive application software including real-time operating system kernels. Software development may begin on RISC System/6000 workstations, eliminating the need for early breadboards. Software development may start at the beginning of the program with the workstation performing the role of the target machine.

Ada and C development environments are both available for the RAD6000, on RISC System/6000 Sun and HP workstations. Included in the RAD6000 software suite is the VxWorks® Real Time Operating



Mars Pathfinder
Lander/Rover

The RAD6000 increases the user's ability to meet space program requirements with real hardware in the concept definition, demonstration, and validation phases.

System Kernel and both the V_xWorks software development environment ("C") and the Green Hills Ada Multi software development environment (Ada and "C"). The commercial elements provide the space software community with current validated software.

Software compatibility between the RAD6000 and the RISC System/6000, extends to IBM workstations based upon the PowerPC providing an excellent growth path.

The RAD6000 processor, in combination with the RISC System/6000 development environment and commercial software base, increases the user's ability to meet space program requirements with real hardware in the concept definition, demonstration, and validation phases.



RISC System/6000 Workstation



Space.
 The unending frontier.
 Lockheed Martin Federal Systems
 is there providing the RAD6000 Processor.

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Ada Multi is a registered trademark of Green Hills Software Corporation.

VxWorks is a registered trademark of Wind River Systems.

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