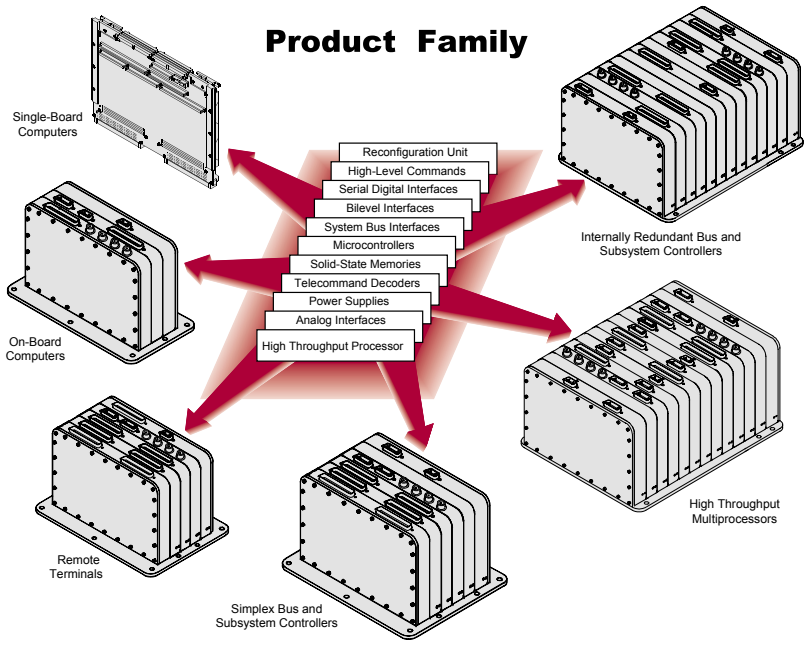
Integrated Spacecraft Controller (ISC) Family

The General Dynamics Advanced Information Systems (GDAIS) Integrated Spacecraft Computer (ISC) product family is a set of modular processors, interfaces, and power supplies that can be efficiently configured to provide a wide variety of low-cost, high-performance systems for spacecraft and payload control. Examples are:

- Simplex and Redundant Bus Controllers
- Very High Throughput Payload Processors
- Single-Board Computers
- On-Board Computers
- Subsystem Controllers
- Remote Terminals



Using selected commercial processors and memory in a radiation-tolerant system architecture provides very high throughput, low-cost, commercial software compatibility, and Single Event Upset (SEU) immunity.

GDAIS has been building and delivering spacecraft computers for over 25 years. We have delivered more than 50 on-board computers to various programs including NASA's HEAO and AXAF. The ISC also benefits from our years of experience building mil-spec and ruggedized COTS-based processors, mass storage devices, and associated COTS-extending software.

The ISC product family is a second-generation, integrated spacecraft electronics system. It succeeds the Central Electronics Unit (CEU) currently flying on an operational communications satellite. The CEU performs on-board computer, telecommand demodulator and decoder, telemetry formatter and modulator, command and data handling system, and attitude control system functions. The internally redundant CEU manages 700 interface signals to other spacecraft subsystems.

Technical Initiatives

The ISC product family provides revolutionary performance at a fraction of traditional costs by using selected COTS technology, by integrating multiple functions into a single unit, by an open systems modular approach using industry standard buses, and by a concurrent design approach for fast and efficient production using modern manufacturing methods.

Processors and System Buses

The ISC product family includes two processors: a high-performance COTS processor and a microcontroller. The high-performance processor currently uses the PowerPC 603 series microprocessor in a proprietary, fault-tolerant architecture to provide high-performance processing with high reliability and availability.

The microcontroller is an 8086 instruction set computer embedded in a custom ASIC that provides error correcting memory,

internal bus, and external interface support. The microcontroller can be used standalone, or as part of an intelligent interface card.

All processors support MIL-STD-1553B serial spacecraft data buses using either standard or low-power electrical interfaces at 1 Mbaud. All serial system bus interfaces can operate as either bus controllers or remote terminals, software selectable.

ISC Bus Controller Architecture

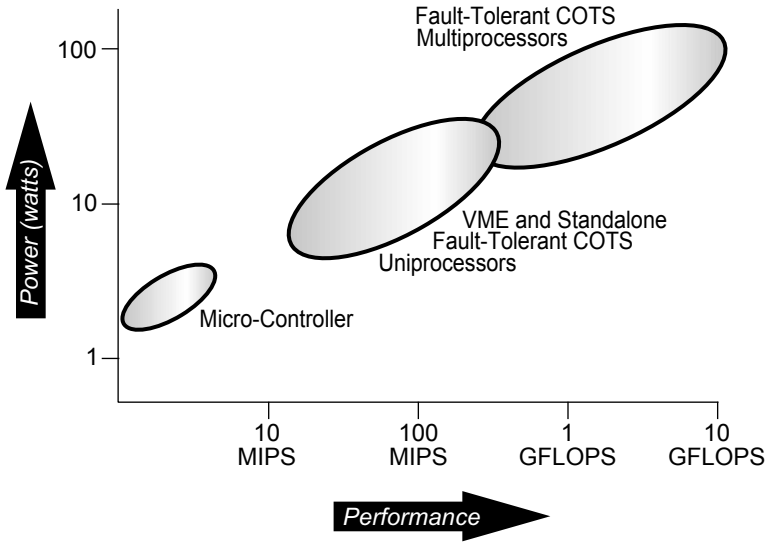
The major functional blocks of a bus controller are the Telecommand and Telemetry (TTC) unit, the On-Board Computer (OBC), and spacecraft interface cards. The ISC bus controller can be configured as either a single string or an internally redundant unit with cross-strapping between the OBCs and TTC units, and between the OBCs and spacecraft interfaces. For internally redundant units, a Reconfiguration Unit allows both manual and automatic switchover between OBCs.

The TTC interface modules provide simplex or redundant interfaces to redundant transponders. The telecommand decoding is performed by an embedded processor, allowing format flexibility, satellite addresses, authentication algorithms, and direct telecommands. While the CCSDS formats are being implemented initially, other formats such as PSS-45 and Intelsat can be accommodated. Direct telecommands provide ground override of OBC redundancy, and can be extended to control external interfaces.

Telemetry rates up to 10 Mbaud can be generated using list-directed DMA controllers. Convolutional encoding is optional, under software control.

Spacecraft and Subsystem Interfaces

The ISC interfaces to other subsystems and directly to sensors and actuators. Standard modules are available for voltage and thermistor temperature measurements. High-level command modules let the OBCs control relays in other subsystems.



Highest Industry MIPS/Watt Performance

GDAIS or the spacecraft prime can optimize digital and analog interface modules for a particular mission for inclusion in an ISC.

The interface modules connect to the OBCs using the industry standard A16, A24, A32, A40, D8, D16, and MD32 VME bus modes. Mechanical packaging options support the standard 6U VME form factor and a low-weight custom form factor. Passive adapters are available to support rapid development by allowing both form factors to be used in lab configurations.

Payload Processor

This processor is also available in a multiprocessor configuration. A typical system might have six processors installed and be actively using five for a peak of 2,400 MIPS. All processors are connected by a redundant VME bus system, allowing full system memory sharing.

Reliability

To maximize mission life, the ISC employs a three-level reliability strategy of fault avoidance, component fault masking, and functional redundancy.

Fault avoidance demands an inherently reliable design. High-density VLSI technology minimizes both parts count and inter-component connections. CMOS technology and careful physical design provide low semiconductor junction temperatures for longer component life. A parts qualification program assures that all parts have the reliability needed for the spacecraft mission.

Selected parts, such as memories and processors, use fault masking architectures allowing the

system to continue operation with failed or upset components; i.e., all memory is implemented with error detection and correction codes.

The internally redundant systems are free of single-point failures. All internal buses and circuits are redundant. The OBCs, TTCs, interface cards, and Reconfiguration Unit are separately powered and serve as fault containment regions.

Verification

The product family has been designed with reliability, manufacturability, and environmental survivability in mind. Considerations for radiation, temperature, and end-of-life are included in the initial circuit design.

Software verification includes: extensive field testing (COTS OS), peer reviews of new development products, and automated assessment of test coverage for new development software. These thorough assessments provide confidence that these products will meet program requirements for schedule and cost without jeopardizing satellite or mission integrity.

Availability

Our use of commercial processors and operating systems allows customers to begin mission planning and software generation at an early stage of the program. In some cases, commercially available units will satisfy initial needs due to commonality between what is commercially available in a laptop, for example, and what we will provide in a flight unit. When a form, fit, function engineering unit is required, a laboratory model is often available within a few weeks (ref. photo below). Flight units can be delivered as soon as 12 months ARO.

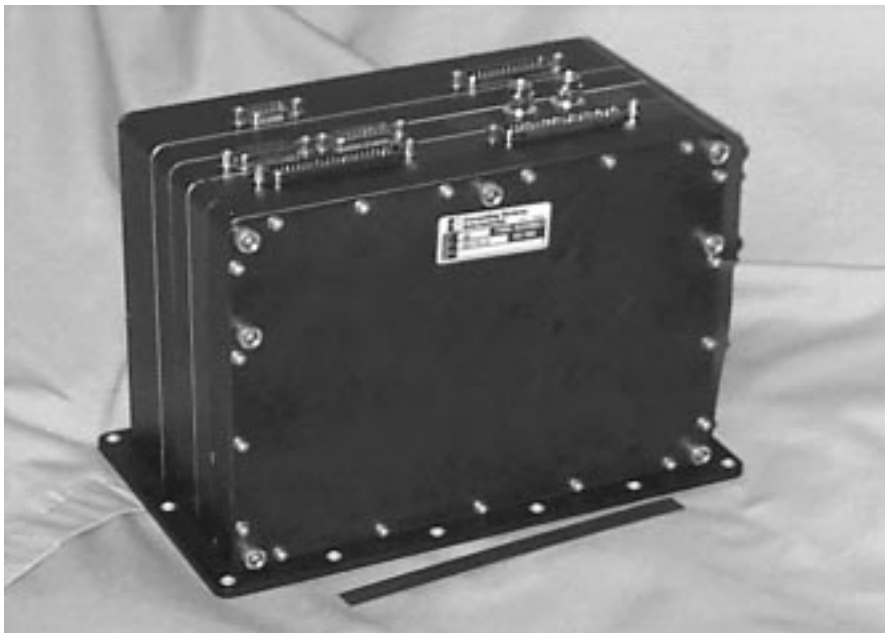
Packaging

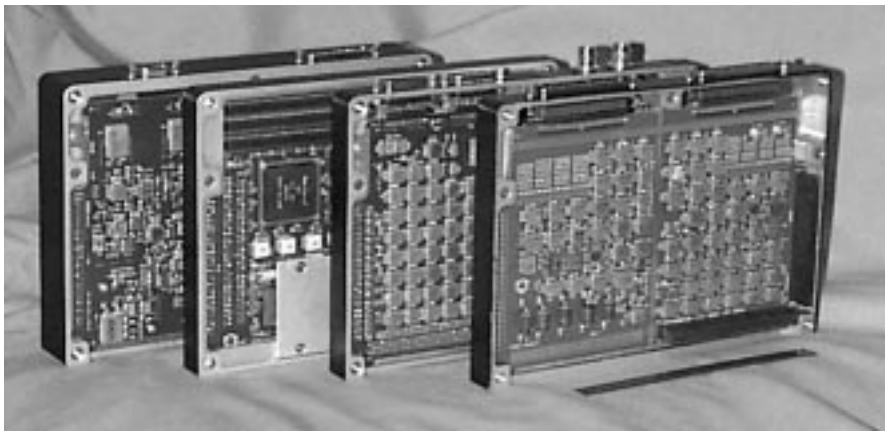
Custom and standard VME formats are available. The ISC flight hardware uses a unique, dual-sided board-in-frame module with integral heatsinking and surface mounted devices. Similar construction is proven in our 469R2 and 444R2 computer series, which have logged over 1,000,000 hours of operation in space without delaying a launch or terminating a mission.

Packaging features include:

- Board-in-Frame construction. There is no separate enclosure, card cage, or backplane.
- Extremely rigid mechanical design.
- Excellent thermal control (typical dT < 20 degrees C, baseplate to junction).
- Capabilities expandable using additional modules without changing thermal characteristics.

The high throughput COTS processor is also available in a conduction-cooled VME compatible form. This single-module computer can be used in any chassis compatible with the IEEE 1101.2 standard and is also compatible with commercial 6U VME card cages. In this form, A16,





SPECIFICATIONS

	On-Board Computer	VME Compatible On-Board Computer	Single-String Controller	Redundant Platform Controller	High-Throughput Multiprocessor	Redundant Remote Terminal
Instruction Set	PowerPC	PowerPC	PowerPC	PowerPC	PowerPC	8086
Peak Throughput	480 MIPS	480 MIPS	480 MIPS	480 MIPS	1200-2400 MIPS (Scaleable)	1 MIPS
Processor RAM	256/512 MB	64/128 MB	256/512 MB	256/512 MB	160-1280 MB	8 MB
Non-Volatile Program Storage	32 MB	16 MB	32 Mb	32 MB	160 MB	256 KB
DMA Channels per Active Side	5	5	10	10	20	5
System Bus	2-1553	1-1553	2-1553	2-1553	2-1553	2-1553
Other Interfaces	3-High-Speed Serial, VME Bus	3-High-Speed Serial, VME Bus	Analog and Digital Interfaces	Telecommand and Telemetry, Analog and Digital Interfaces	High-Speed Serial and Parallel	Analog and Digital Interfaces
Typical Size (Exclusive of Mounting Flange)	9.5 x 6.5 x 3.3 (3 Modules)	Single-Width IEEE 1101.2 Conduction-Cooled, Compatible with 6U	9.5 x 6.5 x 4.8 (5 Modules)	9.5 x 6.5 x 9.3 (10 Modules)	9.5 x 6.5 x 13.8 (12 Modules)	9.5 x 6.5 x 4.8 (4 Modules)
Typical Power (Watts)	5 - 20	5 - 20	5 - 25	10 - 35 (Warm Spare)	50 - 100	<8
Weight	3.5 Kg	1.2 Kg	5 Kg	9 Kg	12.5 Kg	4.5 Kg

SPECIFICATIONS

Processor Mean Time to System Upset (LEO orbit)	>1000 Years
Total Dose Tolerance (LEO Orbit to 1400 Km)	>10 Years
Total Dose Tolerance (GEO Orbit)	>15 Years

A24, A32, A40, D8, D16, D32, and D64 VME modes are also available.

The ISC family can be repackaged into custom board formats for a standard engineering charge.

Software Development

The ISC is based on commercially popular processors and is supported by commercially available toolsets. Ada, C, and C++ compilers are available for use. GDAIS has developed I/O driver packages and integrated them with the VxWorks® real-time operating system from Wind River Systems. Software elements are also provided to access other non-I/O, non-processor ISC capabilities. No modifications to the commercial toolsets or operating systems are needed other than the GDAIS-provided board support package customization.

Support Equipment

The ISC system includes a complete suite of hardware and software tools for software development, system integration, and system checkout (provided by GDAIS).

Tools are available to support software development on a PC or UNIX system. Connection to the ISC is through RS-422 and Ethernet. The Wind River Tornado development system can load programs in the ISC, monitor system operations, execute program development tools, and perform debugging.

An I/O Tester (IOT) has been developed for ISC testing that is also capable of evaluating spacecraft systems for application software test and checkout. Under control of the public domain TCL command scripting language, the IOT can emulate all the analog, digital, and 1553 I/O the ISC unit exchanges with the spacecraft systems.

Emulators for custom modules are easily added to the IOT because it uses standard PC and Sun computers and VME/VXI hardware interface modules. The IOT software is written in Microsoft C, and the system includes a library of driver routines for easy customization.

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