How to Develop Reliable Spacecraft Systems at Lower Cost with the Ada Programming Language

How to Develop Reliable Spacecraft Systems at Lower Cost with the Ada Programming Language

When SEAKR Engineering decided to upgrade its mission-critical data recorder applications to a new hardware platform, they kept their software in Ada. To improve their Ada code's efficiency and reliability, they upgraded their development environment to GNAT Pro.

BACKGROUND

A leader in spacecraft-based data collection and processing

SEAKR Engineering is a leading supplier of state-of-the-art spacecraft electronics. They specialize in the design and manufacture of highly customized systems, including solid-state data recorders, modular command and data handling systems, high-performance payload processors, and more.

They were a pioneer in the on-board data recorder field, replacing the magnetic tape recorders used on early weather and surveillance satellites with modern solid-state recorders and support systems that supply data more efficiently to users on the ground.

Today, SEAKR's products are on the International Space Station, on satellites orbiting the earth, and on probes that have traveled to Jupiter. They help explore Earth's atmosphere and relay climate and operational weather data critical to global climate science. They fortify U.S. intelligence and contribute to improving the U.S. battle network by advancing its space-based capabilities.

THE CHALLENGE

Transferring older software baselines to new embedded platforms

SEAKR has been using Ada on its data recorders since the late 1980s. Previously, most of their systems had used a Tartan Ada toolset on a MIL-STD-1750 platform—a hardware configuration which by that time was thirty years old. When they decided to upgrade to a new LEON3 processor a few years ago to take advantage of its radiation tolerance, they were presented with some challenges.

First, they needed to port over their Ada code from the previous platform, and they wanted to restructure it using more object-based and object-oriented concepts. They also needed a new

Customer
SEAKR Engineering is a leading supplier of state-of-the-art spacecraft electronics and a pioneer in the development of solid-state data recorders for satellites.

Problem
They needed to port their data recorder application software in Ada to a more modern hardware platform and to restructure it using object-oriented techniques.

Solution
SEAKR selected AdaCore's GNAT Pro as their new integrated Ada development environment for its robust and efficient GNAT compiler, its comprehensive, easy-to-use toolset, and its support for bare metal configurations.

Results
The transition to the new hardware platform was smooth and efficient. SEAKR has been extremely pleased with the performance of the GNAT Pro compiler and toolset and with AdaCore's support services. They are saving money through early detection and correction of errors, thanks to Ada and GNAT Pro.

integrated development environment (IDE), Ada compiler, and toolset to help them do that restructuring with greater efficiency.

The benefits of Ada

Ada was chosen because SEAKR's baseline recorder application was already written in Ada. And Ada code is highly portable and reusable when moving from one platform to another. At the same time, SEAKR's principal software engineer suggested moving development to AdaCore's GNAT Pro tools.

This was great news for Mike Jelks, a staff engineer at SEAKR, who has been programming in Ada for over 30 years. He well understands the benefits of Ada's strong typing, tasking, protected objects, and object-oriented features.

"By using strong typing properly, you can reduce your errors and catch them at compile time rather than later on in the development process," says Jelks. "Ada discourages or prevents many of the bad programming practices that typically cause problems in C and C++. Common errors that you'd make in a language like C, you're much less likely to make in Ada."

THE ADACORE SOLUTION

GNAT Pro – the comprehensive Ada development solution

GNAT Pro is AdaCore's complete solution for producing critical software systems where high assurance (reliability, safety, security), efficiency, and long-term maintainability are essential. The company offers an extensive suite of tools and libraries for developing large mission-critical applications. It supports all versions of the Ada standard, from Ada 83 through Ada 2012, as well as some features from Ada 202x currently undergoing standardization. There are also GNAT Pro editions for C and C++.

> Being able to automatically enforce a coding standard with GNATcheck, rather than having to review code manually, is a huge time-saver. Plus, it eliminates potential human error.
>
> **— Mike Jelks, staff engineer, SEAKR Engineering**

What Jelks likes most about GNAT Pro is its rich integrated development environment, GNAT Programming Studio, or GPS (now called GNAT Studio).

"GPS is easy to use," says Jelks. "You just click, and you find your compilation messages quickly. That's the tool I use every day."

Another tool that Jelks finds helpful is GNATcheck, AdaCore's tool for checking code against an Ada coding standard.

"GNATcheck is really useful because there are many features in Ada that will give you big benefits...if you use them," he says. "A coding standard can force you to label loops, for example. Being able to automatically enforce a coding standard with GNATcheck, rather than having to review code manually, is a huge time-saver. Plus, it eliminates potential human error."

Running on bare metal

On its data recorders, SEAKR's application software runs in a 'bare metal' configuration—directly on the processor's logic hardware without an intervening real-time operating system (RTOS)—as is typical for satellite systems. GNAT Pro facilitates bare-metal Ada applications by providing a "micro-RTOS"—essentially the Ada runtime—which allows the use of tasking and other features that would normally require an RTOS, but with far lower latency, memory use, and power consumption.

GNAT Pro supports numerous platform configurations—including bare metal—as indicated in the chart at right. SEAKR also runs GNAT Pro tools on a native Linux environment, which can be used for unit testing.

Seamless resolution of an early configuration issue

During initial discussions with AdaCore, the target hardware configuration was never really discussed in detail. At the time, GNAT supported LEON2, but SEAKR had obtained a LEON3 UT699 FPGA evaluation board from Gaisler (now Cobham Gaisler), the LEON3 manufacturer, and quickly discovered that there were some significant differences between LEON2 and LEON3.

Jelks immediately got back in touch with AdaCore, who agreed to support the LEON3 processor without hesitation and at no additional cost.

AdaCore worked with Gaisler, and together they came up with a customized UT699 evaluation board and a new, fully tested Ada compiler to go with it.

"They shipped it all to me, gave me the FPGA image to program onto my board, and provided succinct and proper instructions on how to load and use it. The whole effort happened seamlessly, and everything worked the way AdaCore said it would."

SEAKR eventually built their own custom control board for the UT699. Later, they built another for a UT700 processor. Throughout that evolution, Jelks has been impressed by how AdaCore's GNAT Pro compiler has performed.

Platforms	
NATIVE CONFIGURATIONS	
Linux (x86)	✔
macOS (x86)	✔
Solaris (x86, SPARC)	✔
Windows (x86)	✔
CROSS CONFIGURATIONS	
Android (ARM)	✔
Bare Metal (ARM, RISC-V)	✔
Bare Metal (PowerPC, LEON)	✔
Common Code Generator (C)	✔
Embedded Linux (ARM)	✔
Embedded Linux (PowerPC)	✔
iOS (ARM)	✔
Lynx 178 (x86, PowerPC)	✔
PikeOS (ARM)	✔
QNX (ARM)	✔
VxWorks 5 (PowerPC)	
VxWorks 6 (x86, PowerPC, ARM)	✔
VxWorks 7 (x86, PowerPC, ARM)	✔
VxWorks 653 (PowerPC)	✔

Ada saves money through early detection and correction of errors

Jelks thinks that companies who create critical applications—those with a low tolerance for risk—would do well to use Ada, even if they're more familiar with other languages like C and C++.

> "Companies who create critical applications—those with a low tolerance for risk—would do well to use Ada for those applications, even if they're more familiar with other languages like C and C++."
>
> **— Mike Jelks, staff engineer, SEAKR Engineering**

He points to early detection and correction of errors as critical factors, noting that the cost of correcting software errors increases exponentially the later they are detected in the software lifecycle. Ada and GNAT Pro save SEAKR money, he says, because Ada helps prevent many errors that are typical in C and C++. The GNAT Pro compiler detects the vast majority of coding errors during compilation. Others are caught with standard Ada run-time checks, and GNATcheck helps eliminate additional potential errors by enforcing project-specific Ada coding standards.

As an example, Jelks likes to cite a study performed by Bell Labs in 1998 that looked at bugs that made it into a telecom switching system. The study examined millions of lines of code written in C.

Bell Labs classified 17 "logic errors" and 11 "interface errors" that C programmers make frequently. Twelve of those errors are syntactically impossible to occur in a compiled Ada program. Another nine are possible but very unlikely in Ada due to the syntactic structure of the language.

An Ada compiler and toolset for the 21st century

Jelks says the GNAT Pro development environment has made Ada much more efficient and much easier to use than their earlier toolset.

"Performance has never been an issue with this compiler," he says. "And GNAT Pro provides quick and easy feedback for compilation errors, coding style problems, things like that." Jelks has also been pleased with the GNAT Pro toolset.

> "Performance has never been an issue with this compiler. GNAT Pro provides quick and easy feedback for compilation errors, coding style problems, things like that."
>
> **— Mike Jelks, staff engineer, SEAKR Engineering**

"As soon as I started using it, I found it did everything I expected it to do. We've never had to say, 'This toolset isn't working for us. We need to go with another approach'." And since GNAT Pro offers support for bare metal configurations, SEAKR's code runs without the space or time overhead that an RTOS would incur.

Praise for AdaCore support

Jelks also has high praise for AdaCore's technical support team.

"When we have had problems, AdaCore has been very responsive," says Jelks. "Typically, they have gotten back with a solution as quickly and as reasonably as any company could have. The way they supported us in moving to LEON3 is a great example."

He also likes the way AdaCore treats their customers and the attitude they bring to customer service.

Ada for the future

SEAKR now has a new project under development using Ada and GNAT Pro on a Wind River VxWorks target platform. Previously, they had used Ada for data recording applications and C/C++ for data processing applications. This new project brings those niches together in one product.

> "We can take code we've developed, and it still works in these other environments. Wherever our future lies, Ada is right there, ready to go."
>
> **— Mike Jelks, staff engineer, SEAKR Engineering**

"My primary focus on this new project is to show that we can have a file system and everything written for a data recorder that works with the processing system, and we don't have to rewrite all of our code just because it was written in a different language," says Jelks. The GNAT Pro compiler and toolset help with that because support for C and C++ is available as an add-on.

Jelks sees SEAKR moving into other architectures and development environments very soon. He believes Ada and GNAT Pro will be along for the ride.

"We can take code we've developed, and it still works in these other environments," he says. "Wherever our future lies, Ada is right there, ready to go."