WNDRVR

Case Study: VxWorks Powers Thales' Astute-Class Submarine Periscope

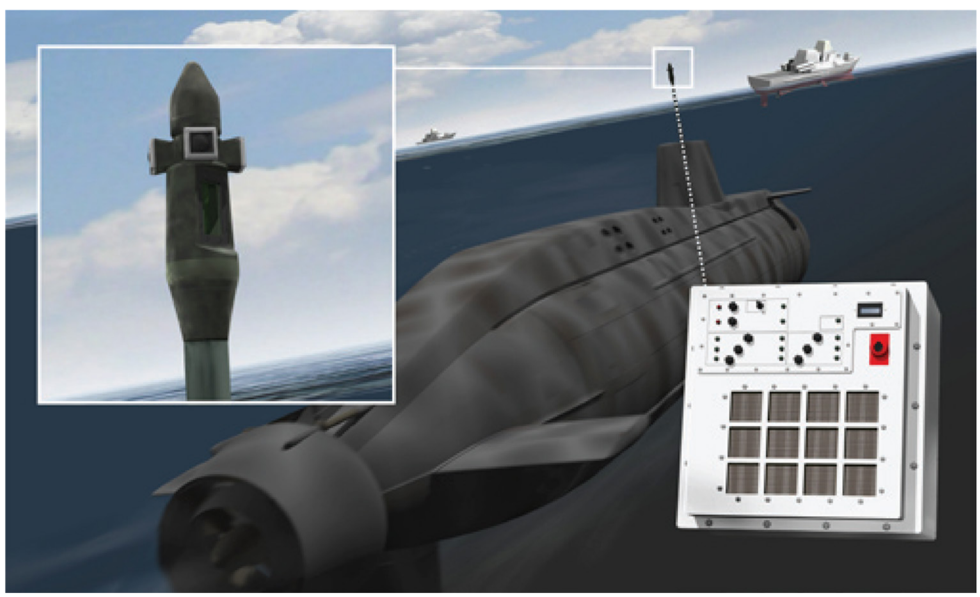
Eur Ing Paul Parkinson
Senior Systems Architect, Aerospace and Defense, Wind River

EXECUTIVE SUMMARY

This case study describes Thales UK's state-of-the-art non-hull-penetrating optronic mast for the United Kingdom Royal Navy's new Astute-class submarines, which provides greater flexibility in boat design and improved surface visibility while reducing the probability of detection. The optronic mast is powered by the VxWorks® mission-critical real-time operating system (RTOS). Its selection and deployment, to fulfill design requirements, is explained.

DESIGNING FOR STEALTH

The Astute nuclear-powered submarine is designed to patrol the world's oceans without being detected by surface ships and other submarines. The Astute deploys a number of technologies to reduce its sonar signature, to minimize the probability of detection while submerged. However, submarines are most vulnerable to detection when the submarine commander uses a periscope to assess the situation on the surface. The probability of detection can be reduced by minimizing the duration that the periscope is above the surface.



However, this conflicts with the need to provide sufficient time for the submarine commander to be able to assess the situation on the surface and make appropriate decisions.

Thales has overcome this problem by using a state-of-the-art non-hull-penetrating optronic mast design instead of a conventional optronic periscope design. The new design enables the sensor head unit (SHU) to be extended from the submarine fin and rapidly perform a 360-degree scan of the surface above, enabling the commander to analyze the image data afterward, minimizing the risk of detection. The SHU is a pressureproof, electro-optical assembly that contains high-performance cameras, optics, environmental sensors, and stabilization mechanisms. It is designed to function in temperatures ranging from minus 15 C to more than 60 C and withstand nearby explosion.

The SHU is used in two configurations on the Astute class submarine. It provides extensive electronic surveillance measures (ESM) through dual redundant high-definition color video operation. The SHU also enables extended capabilities with the two masts providing infrared and low-light operation respectively, with 3-axis image stabilization to subpixel accuracies, as well as a laser rangefinder.

Inside the submarine hull, the mast control unit (MCU) coordinates overall system activity, controlling a number of other units and communicating with the submarine's tactical, data, and combat systems. The MCU controls the equipment that raises and lowers the SHU out of the submarine fin, as well as the azimuth drive module that rotates the SHU and forms part of the stabilization system. This requires deterministic, high-standard servo control to compensate for the submarine's movement in the water. A clear image is critical to mission success.

THE ROLE OF SOFTWARE

The optronic mast uses an Ada application developed using AdaCore GNAT running on the VxWorks RTOS, providing a reliable system that is essential for this mission-critical application. The application controls the stabilization system, video, and thermal camera, communication with the in-hull systems, and all of the mechanisms and motors in the SHU.

The MCU in the submarine hull uses two processors running VxWorks to raise and lower the SHU out of the submarine fin, and it also controls the azimuth drive module that rotates the SHU and forms part of the stabilization system. This requires deterministic, high-performance servo control to compensate for the submarine's movement in the water and provide a clear image.

"Obviously a system like the optronics mast must be robust and highly reliable at all levels. Without it the submarine is blind. VxWorks was chosen because it provides a high-performance, reliable environment," explains David Cookman, Systems Engineer for Thales' optronics facility in Glasgow, Scotland.

DEVELOPMENT CHALLENGES

Thales' previous optronic mast design had used an Ada application that performed image stabilization, I/O, and control and ran on a quad digital signal processor (DSP) hardware design based on the military-grade Texas Instruments TMS320C40. These specialized devices are made to withstand extreme environmental conditions such as temperatures as low as minus 30 C during operation on a submarine and severe shock on military fast jets and helicopters.

For the new design, the Thales Computers V4G4c quad PowerPC 7410 AltiVec commercial off-the-shelf (COTS) board was selected. The quad processor design provided some commonality with the quad DSP architecture previously used, but there were a number of significant architectural differences that presented Thales with some development challenges. These included mapping the software architecture from the DSP to the general-purpose processor and migrating from a scheduler and the Texas Instruments DSP Ada compiler to the VxWorks RTOS and AdaCore GNAT Ada compiler. The migration from the DSP to the general-purpose platform is a significant step; however, Thales has standardized on Wind River platforms for device software and uses a common toolset and software architecture across projects wherever possible. This standardized approach enables Thales to leverage skills within the engineering organization across projects.

"VxWorks has a pedigree that makes it an obvious choice for use in a high-reliability, safety-related environment. Added to this, its support for multiple platforms has allowed Thales to rationalize its use of third-party RTOSes and thereby reduce target platform variability from one project to the next. This consistency between projects, through standardization on VxWorks, results in development cost savings," said Jack Cunningham, Head of Discipline (Software) for Thales UK's optronics business.

The quad 'C40 DSP hardware architecture and quad PowerPC hardware architectures have a number of significant differences, which could have impacted the portability and reuse of the Ada image stabilization software. First, the 'C40 DSP has six dedicated high-performance communication ports that can be directly connected to other 'C40s, whereas the PowerPC processors are connected via a shared bus and shared memory. Thales was able to minimize the impact of these architectural differences by simulating the communication ports in software by using packeted data in shared memory in conjunction with VxWorks shared memory semaphores to provide atomic access and efficient interprocessor synchronization. Second, the processor endianism differs on the DSP and PowerPC. This is further complicated when performing transfers between boards over the VMEbus; however, Thales was able to overcome this through configuring the VxWorks board support package

(BSP) to use the appropriate VME addressing modes for data transfers. This hardware simulation and software abstraction at the lower level enabled Thales to reuse its proven image stabilization algorithms.

Thales also needed to synchronize the four PowerPC processors on system startup and confirm that the application met its performance requirements. In the development of the earlier DSP-based design, by instrumenting the application to write trace values to the VMEbus, it could be logged with a VMEbus analyzer and subsequently analyzed. In the PowerPC-based design, Thales was able to embed user events within the application and display these graphically in the Wind River System Viewer, showing their context within overall system operation while providing accurate timing information without the overhead of generating additional VMEbus traffic.

The system also needed to be configured for standalone deployment. For this Thales was able to link the Ada application with the VxWorks kernel for each of the nodes on a VxWorks True Flash File System (TFFS) on a PowerPC board. This enabled the system to start up automatically from system power-up without external intervention.

SUMMARY

Thales has developed a state-of-the-art periscope system that will provide significantly enhanced capabilities for the UK Royal Navy. The advanced interprocessor communications capabilities of VxWorks enabled Thales to migrate its applications from a custom DSP architecture to a COTS PowerPC platform, and the powerful development tools within the Wind River platforms enabled Thales to overcome challenges during the development. In addition, by standardizing on Wind River platforms, Thales has been able to leverage skills within the engineering organization across multiple projects and reduce development costs.

ABOUT THE AUTHOR

Eur Ing Paul Parkinson is a Senior Systems Architect with Wind River, working with customers in the aerospace and defense sectors in the UK and Nordic countries. His professional interests include Integrated Modular Avionics (IMA) and Intelligence Surveillance Target Acquisition Reconnaissance (ISTAR) systems. He blogs on A&D industry issues on the Wind River website at blogs.windriver.com.

ABOUT THALES

Thales is a leading international electronics and systems group, addressing defense, aerospace, and security markets worldwide. Thales' leading-edge technology is supported by 22,000 research and development engineers who develop and deploy field-proven mission-critical information systems. To this end, its civil and military businesses develop in parallel and share a common base of technologies to serve a single objective: the security of people, property, and nations. It builds its growth on its unique multidomestic strategy based on trusted partnerships with national customers and market players, while leveraging its global expertise to support local technology and industrial development. Thales employs 68,000 people in 50 countries with revenue in excess of £8.3 billion in 2007.

Thales UK is a major electronics and systems group serving defense, aerospace, security, and services markets. Thales UK employs 9,000 people in the UK, based at more than 50 locations. In 2006, Thales UK's revenue was more than £1 billion. For more information, go to www.thalesgroup.co.uk.

ABOUT WIND RIVER

Wind River is a global leader of software for mission-critical intelligent systems. For 40 years, the company has been an innovator and pioneer, powering billions of devices and systems that require the highest levels of security, safety, and reliability. Wind River offers a comprehensive portfolio of software and expertise that are accelerating digital transformation across industries.

WNDRVR