Kwajalein Modernization and Remoting Project Replaces Four Unique Radar Systems With One Common Design

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CrossTalk

The Kwajalein Modernization and Remoting (KMAR) project is a five-year program designed to reduce cost and improve capability at the Reagan Test Site by modernizing software and hardware. The challenge was to replace aging, complex, one-of-a-kind radar software systems at each of the four radar sites with a single common design based on Radar Open System Architecture. This article details how the team succeeded in improving the KMAR radar sites while lowering operating costs.

The Ronald Reagan Ballistic Missile Defense Test Site, 2,200 miles southwest of Hawaii on a ring of tiny coral islands called the Kwajalein Atoll in the Republic of Marshall Islands, is home to four unique signature radar sites: ARPA (Advanced Research Projects Agency) Lincoln C-Band Observables Radar (ALCOR), Millimeter Wave Radar (MMW), ARPA Long Range Tracking and Instrumentation Radar (ALTAIR), and Target Resolution and Discrimination Experiment (TRADEX). They are world-class instrumentation sensors that operate at frequencies between 158 MHz and 35 GHz. Due to their age and layered upgrades during the past 35 years, the sensors were badly in need of modernization.

It was very expensive for the U.S. Army to support these vital resources primarily because many highly specialized engineers commuted daily by air from Kwajalein Island to maintain the radars. The Kwajalein Modernization and Remoting (KMAR) project was a five-year program designed to reduce the cost and improve the capability of these radar sites by modernizing all software and hardware except antennas and transmitters.

The challenge was to replace aging, complex, one-of-a-kind radar software systems at each of the four radar sites with a single common design based on Radar Open System Architecture (ROSA). During a 35-year span, the legacy systems had been written in more than a dozen computer languages (primarily Fortran) representing millions of lines of code, ran under a variety of obsolete operating systems and computers, and were difficult to maintain. The legacy systems were manually controlled and lacked simulation and remote operation capabilities. These shortcomings resulted in very high support costs, reliability suffered, and the systems were cumbersome to improve.

The KMAR has been highly successful in solving the legacy systems' deficiencies. The radar sites' maintainability is greatly enhanced by employing a single common software solution that reduces lines of code by more than 70 percent and incorporates modern software languages, up-to-date operating systems, and a rigorous configuration control system. Reliability is greatly improved by thorough testing with advanced simulators prior to software release. By employing a single common solution, a given improvement now only needs to be implemented once to benefit all operational systems. The number and skill level of required personnel has been reduced.

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The Delivered Product

The KMAR hardware and software were installed sequentially during two and one-half years. TRADEX, the fourth radar to be modernized, achieved initial operating capability (IOC) in February 2003. The KMAR software is now the operational control system for all of the instrumentation radar sites. The software comprises a real-time radar control program, operator control and display systems, high-fidelity radar and multi-target simulators, playbacks for review of past missions, automated calibrations, and embedded subsystem software.

About 720,000 lines of code comprise the KMAR software. The radar real-time program (RTP) is approximately 300,000 lines of code. A single common software base now supports all operational radar sites, i.e., each radar runs identical, executable code. This feat was achieved by writing software that is hardware-independent and is fully configured by initialization parameter files. These files describe a radar's unique parameters such as frequency, waveforms, and beam-width. All software systems operate with this same one executable philosophy.

Each radar system, except the antenna and transmitter, was designed and assembled at the Massachusetts Institute of Technology Lincoln Laboratory in Lexington, Mass. All systems were delivered on schedule and on budget. After two years of development, the ALCOR radar was delivered to the site for testing and integration. Four weeks after arrival, it tracked its first satellite. The MMW radar was delivered the following year and the first satellite track was taken three weeks later. ALTAIR was delivered at the end of fiscal year 2002. Both ALTAIR and TRADEX tracked satellites only two weeks after installation on Roi-Namur. This rapid integration was largely due to a highly sophisticated simulation capability that allowed rigorous validation.

The KMAR has improved both the efficiency and productivity of the range, says David Villeneuve, technical director for RTS at the U.S. Army Space and Missile Defense Command. Efficiencies include a permanent reduction of greater than 100 work-years of effort per year, mostly from technical staff reductions in the radar area due to matrixing personnel and streamlining maintenance. The radar sites' staffing levels are less than one-half the levels required 10 years ago. Prior to KMAR, approximately 150 radar support people flew to Roi-Namur daily. The KMAR allowed a greater than 50 percent reduction in aircraft seating requirements.

Productivity improvements include more comprehensive target coverage. All radars can now automatically track multiple objects within their beams, something that ALCOR and MMW could not do previously. In addition to ALTAIR's 128 hours per week of space surveillance support for Space Command, now more TRADEX data is provided for the same or lower cost. Space object identification images have increased from 200 annually to 300 for the same cost.

From 75 percent to 80 percent of hardware and software are now common. The modernized C/C++ code is roughly one-third the line count of the legacy software; system complexity is commensurately reduced. KMAR has resulted in a nearly tenfold reduction in the amount of equipment, says Villeneuve, replacing roughly 100 racks of equipment at each radar by a single row of 12 racks.

Automated radar diagnostic tools have simplified maintenance and operations and improved system flexibility, e.g., by sharing operations and maintenance personnel. To eliminate the daily commute to Roi-Namur, operators now routinely remotely control and diagnose the radar sites from consoles located in the centralized mission control center on Kwajalein Island. This change alone has saved the range more than $5 million annually.

"This is the most comprehensive upgrade attempted and completed in Kwajalein's 40 years of operation," says Villeneuve. "Overall the project is saving the U.S. Army Kwajalein Atoll Reagan Test Site, Space and Missile Defense Command, and the range's customers $17 million per year."

The Development and Build

"The team faced some key challenges," says Stephan Rejto, project manager. "Programmatically, because various groups had been operating these one-of-a-kind systems, no one really believed the four different radar sites could operate with a common system. Technically, trying to isolate the key critical path items was challenging," he says. "Projects fail when you don't identify and tackle the risks up front."

Having the right people carry out a project of this magnitude was also critical. "Many of the people working on the project had a lot of experience with Kwajalein sensors," says Bill Jaros, software manager. "We felt we had a very good command of what had to be done." About 30 percent of the software team were seasoned professionals who could be teamed up with others who were less experienced.

One of the key methods of managing this large software development was to enforce and exploit design modularity. Small teams of one to three developed each subsystem and functional module. Interfaces between modules were clearly defined early in the project. The software team included MIT Lincoln Laboratory and Raytheon RSE engineers at both Lexington, Mass., and the Kwajalein Atoll radar site. This participation by end users in the development and testing cycles significantly minimized final integration and acceptance issues.

"A lot of credit goes to Bill and the system engineering team for decomposing the software into bite-sized chunks that could be assigned to individuals," says Rejto. "That allowed everyone to take ownership of a piece of the system."

Incremental software development was used. "We follow the build-a-little, test-a-lot principal that is clearly the model for incremental development," says Rejto. An initial core real-time capability was established early. Incremental changes were added and tested frequently to minimize risk of failure and simplify regression testing. A loosely coupled architecture facilitated integration. Only working modules were moved to the next level of integration. The process depended heavily on high fidelity radar and target simulators developed as part of this project. Daily testing of new builds with automated scripts ensured constant integrity of the baseline code.

"We were big on having the system operational as soon as possible," says Rejto. "The very first build established a working scaffold for subsequent development. After that first scaffold was up, we always had an operational system. We then integrated new modules and tested to ensure continued operability."

"With these builds, we were able to demonstrate increased functionality to the customer as we proceeded," says Jaros.

Before each operational release, the software underwent a comprehensive integration and test period led by the systems group. All features were tested first with simulators at the development facility, followed by full-system testing with live satellite tracks at site. Finally, prior to IOC, each sensor supported an atmospheric re-entry vehicle mission. In addition, the customer performed a formal acceptance test prior to final validation of each radar.

The KMAR signature radar sites in the order they were modernized, counter clockwise from bottom left, ALCOR, MMW, ALTAIR, and TRADEX.

"The simulator was key to the success of this program," says Jaros. "It was built in-house as part of the program and was used for the entire system checkout." It is a very sophisticated, high fidelity, real-time simulator that basically allows the real-time program to cycle just like it would with the real radar. Jaros adds that it is also very important for operator training. "We believe that about 30 percent to 35 percent of the development effort should be devoted to support tools like the simulator to optimize software development."

With common software, once problems are identified the solution is applied to all radar sites, making each succeeding release more error-free. The current change request rate for the operational radar sites is approximately two per month. Dozens of ballistic re-entry events and thousands of spare tracks have been supported by the modernized sensors. The reliability of these radar sites is demonstrated by the fact that they have been 100 percent successful in fulfilling all mission requirements since becoming operational.◆

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