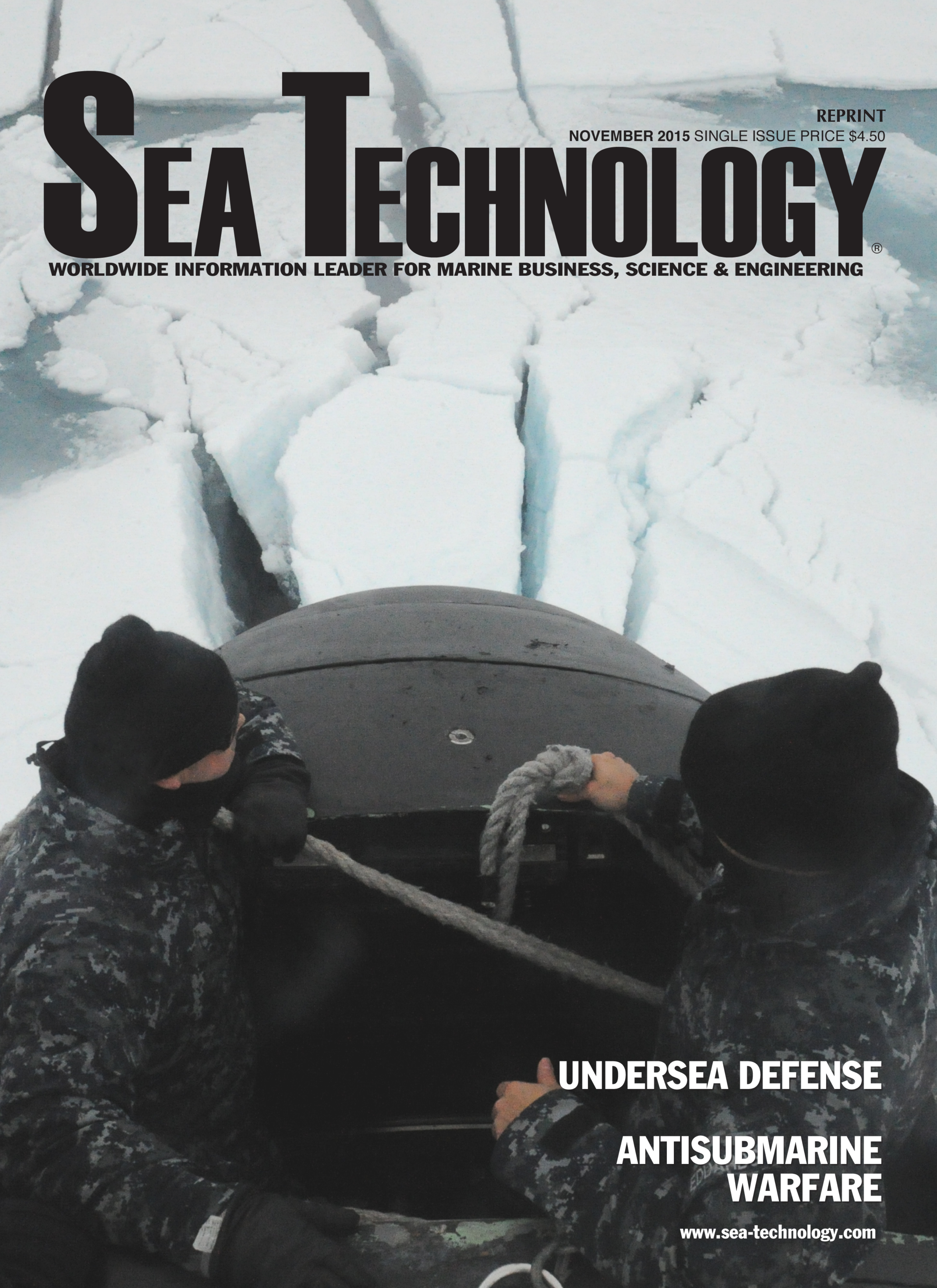

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Submarine Combat Systems Engineering

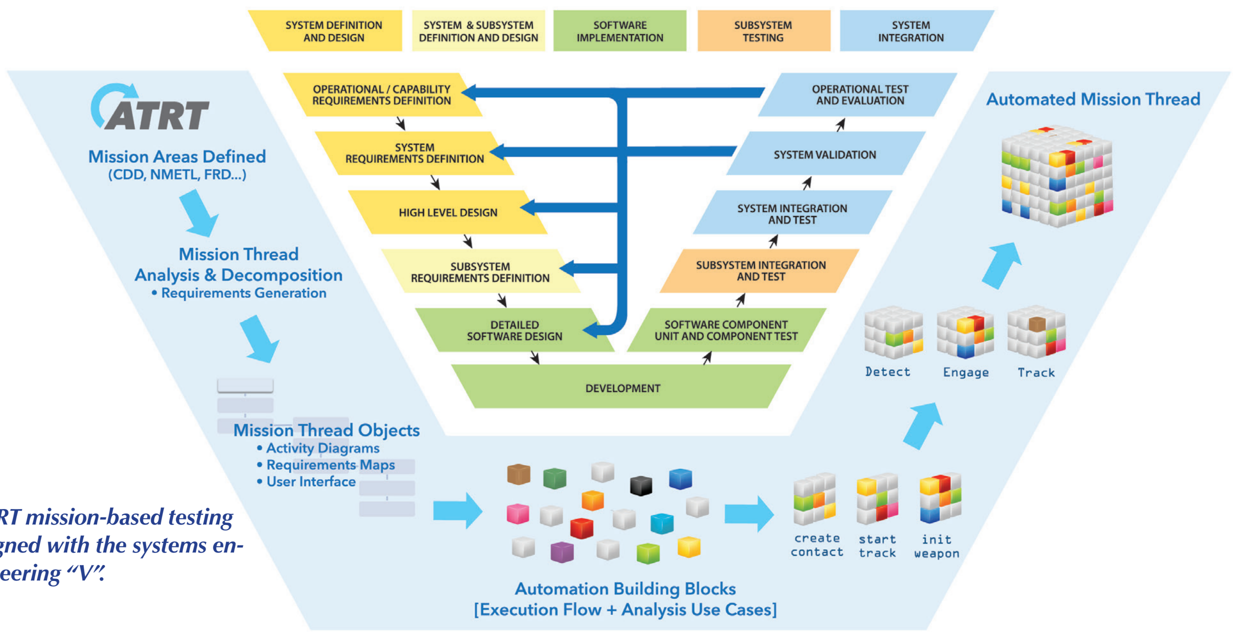
Application of Mission-Based Testing to Complex Undersea Systems

By Bernie Gauf • Burt LeJune

As undersea combat systems evolve to adopt the latest networking and processing technologies to handle advanced algorithms that are the core of enhanced warfighting capabilities, their complexity presents new challenges to the undersea warfare test community. These systems are increasingly composed of networks of various interacting systems, integrated with one another into a larger "system of systems" with greater complexity than the individual components. As system complexity grows, so grows the number of requirements that must be verified to ensure the systems perform as required by the fleet.

Additionally, before Navy program managers can send these new capabilities to the fleet, they must attain a threshold level of confidence that the systems they are fielding can and will operate across the spectrum of environmental and operational conditions that fleet operators can reasonably expect to encounter at sea. The combinations and permutations of the aforementioned ever-growing requirements along with the anticipated environmental and operational conditions create a level of complexity and scope of workload with which human capital resources employing traditional incumbent test and evaluation practices cannot keep pace.

For the U.S. Navy to introduce new capabilities to the fleet more rapidly, as is necessary in a threat environment where technology evolutions occur in months versus decades, a new methodology of testing is needed. These undersea systems require improved approaches for integration and testing to support modifications, lifecycle extensions, and responses to emerging threats and changing environments. Engineers must be equipped with the ability to test and verify new and existing functionality more efficiently



ATRT mission-based testing aligned with the systems engineering "V".

(Photo Credit: U.S. Navy)

(Photo Credit: U.S. Navy)

(Top) The USS John Warner *(SSN-785). (Bottom) A scene inside the* USS Texas *(SSN-775).*

and more effectively. One such means of achieving improved testing efficiency and effectiveness is the use of automation in mission-based testing.

Mission-Based Testing

The widely known systems engineering "V" that defines the process of engineering new operational capabilities is composed of sequential steps, including: system definition and design, system and subsystem definition and design, software implementation, subsystem testing, and system integration. Each of those steps is composed of more sequential substeps that include defining operational requirements and decomposing them.

The left side of the "V" is where the predevelopment system engineering is done, the bottom of the "V" is where the development occurs, and the right side of the "V" is where integration and testing are accomplished. Mission-based testing uses the systems engineering "V" with a focus on ensuring the system's mission requirements are verified in addition to the derived functional requirements.

Innovative Defense Technologies (IDT) of Arlington, Virginia, has been a pioneer in applying automation to U.S. Department of Defense (DOD) mission-based testing, especially with U.S. Navy and Missile Defense Agency systems. IDT's approach is to start with the operational or mission requirements, identify the critical system threads that support those mission requirements, and describe the system behaviors (i.e., message flows and sequences between components) that construct those mission threads. Next, system, subsystem and software requirements are mapped to the system behaviors, and the requirements verification methods are then mapped to each of the requirements.

These steps are completed using a System Modeling Language (SysML) model, which provides a means to design test flows and analysis use cases, and to generate the software required to execute, maintain and update those test flows and use cases. The model-based approach provides the ability to construct operational or mission-level automated test flows and analysis cases from the component or functional levels' automated "building blocks". This process allows for significant reuse of those building blocks as more and more mission thread test flows and analysis use cases are constructed. Additionally, the SysML model provides a concise and accurate format for conducting verification and validation of the underlying analysis methodology.

Benefits of Automated Mission-Based Testing

IDT utilizes Automated Test and ReTest (ATRT) technology to apply automation to mission-based testing. The ATRT test environment combines Model-Based Systems Engineering (MBSE) with test automation to enable continuous integration for the Navy's most critical undersea platforms. As such, ATRT enables the undersea community to more quickly adapt to constantly changing conditions and better meet emerging threats.

Applying automated mission threads to drive automated operational analysis provides constant measurement and tracking of requirements (key performance parameters, key system attributes, etc.) while satisfying developmental requirements. The depth of testing is increased by altering conditions like execution input parameters. Test coverage is increased by including a thorough mapping of requirements at all levels (software, system, interface, etc.). Test rigor is improved by repeatedly executing and evaluating the mission threads each time the system behavior for that mission thread is exercised.

The ATRT-enabled approach of linking automated test flows through the SysML model provides the ability to conduct highly effectual "end-to-end" automated testing and analysis. This methodology yields a multitude of testing efficiencies and benefits.

First, the processing power behind automation enables significantly faster analysis of large quantities of data. Also, automation of test execution is faster in terms of labor hours. For example, a 24-hr. endurance test that previously required 10 testers to run, with automation would require only one tester. Additionally, automation of test execution is generally faster in terms of time and is always faster in terms of labor hours.

Because of the time savings described above, testers are able to conduct more permutations of tests in the same amount of time. With each permutation, testers are able to examine the system under different conditions with different inputs, yielding more coverage of the operational envelope in which the system will be deployed.

With the increased coverage afforded by additional permutations, program managers and certification agents gain higher confidence in determining the system's readiness for deployment. This has the added benefit of reducing the number of unknown operational shortcomings that might be discovered post-deployment, where the cost to repair is greatest.

Another benefit of this approach is the enhanced ability to conduct performance trade-offs. The expanded depth and breadth of test data analysis made possible by automation provides decision makers with the information required to assess system performance following changes, updates or fixes.

These examples of efficiencies and benefits have been realized using ATRT in more than 75 programs of varying complexity and technical modernity over the last several years. On average, improvements—in terms of reduced test time, test personnel and/or test coverage—have exceeded 75 percent. Often, the improvements are much greater.

In Navy programs where automated, mission-based testing is being used via ATRT, customers have been able to increase testing efficiency for the critical systems to which it was applied, resulting in a significant reduction in the time and manpower required to verify the associated requirements and system performance. These customers have also experienced improved collaboration among test teams, as the application of ATRT facilitated the more efficient sharing of analysis cases. Lastly, these programs have been able to increase requirements coverage and expand data evaluation, leading to improved software quality and reduced risk.

Conclusion

Since 2006, IDT has been engaged with the U.S. Navy submarine community applying test execution automation to various undersea warfare programs and supporting integration, regression and installation testing for those systems.

U.S. Navy submarine acquisition managers have set the standard for Navy programs in collapsing the time from the identification of fleet requirements to the fielding of associated fleet capabilities.

A challenge with this enviable speed of delivery is the reduced time available for testing. In this compressed timeframe, testing the new capabilities across the variety of conditions in which the systems will operate becomes more difficult. Also, confirming that system requirements, if met, also satisfy the mission operational requirements remains a challenge. Mission-based testing as described above can provide a way to expand that test coverage, including assessing more conditions and requirements for more mission threads within the accelerated drumbeat of new capability deliveries. Ultimately, mission-based automated testing enables new ideas and requirements to be translated and delivered to the fleet—in the form of new capabilities—faster and with higher confidence. **ST**

Bernie Gauf is one of the founders and the CEO of IDT. He leads the company's strategy for developing and delivering automated test and analysis solutions for the DOD. Gauf is co-author of the book "Implementing Automated Software Testing" (Addison-Wesley, 2009) and holds multiple patents regarding automated test and analysis. He received a degree in electrical engineering from the University of Illinois.

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