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BAE Systems' virtual system of systems

Testbed addresses JADC2 sensor-to-shooter limitations

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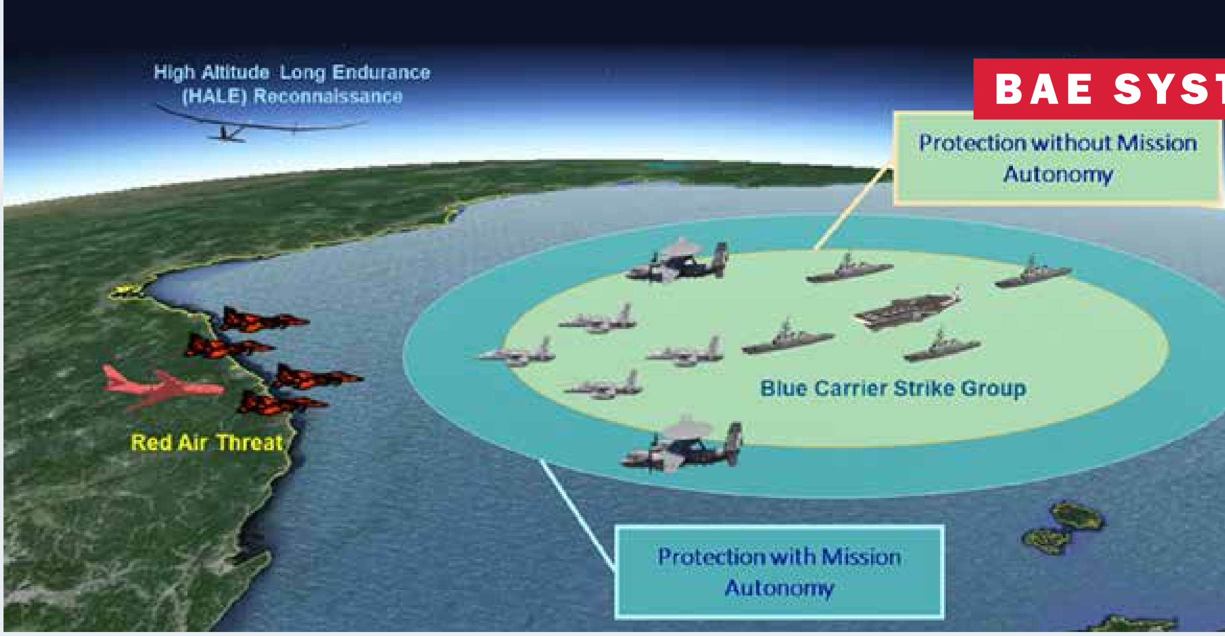
BAE Systems has developed a virtual system of systems (VSoS) testbed to enable detailed quantitative mission-level analysis of kill chain performance in a variety of multi-domain scenarios. The testbed combines high fidelity platform and sensor simulation with detailed modeling of kill chain information flows.

The company developed the testbed to assess technologies for achieving the unprecedented scale of standoff targeting against hardened, mobile, and dynamic targets that future conflicts involving Joint All-Domain Operations (JADO) will require. These mission will only be possible through the effective use of sensing, command and control (C2), and targeting assets across multi-domain kill chains. Technologies such as artificial intelligence (AI) and autonomy are critical to enabling effective, scalable, and timely kill chains, but only if applied appropriately to address kill chain limitations, informed by quantitative SoS modeling and simulation at the data level.

JADO kill chains: sensor-to-shooter

JADO is the U.S. Department of Defense's (DoD) joint warfighting concept, with a goal to align all services and domains—space, air, maritime, land, cyber, and electromagnetic spectrum—to respond more effectively, efficiently, and quickly to advanced threats. JADO includes Joint All-Domain Command and Control (JADC2), which will enable warfighters across all services and levels to sense, make sense, and act using available information. To achieve this vision, the individual forces must act as one synergistic group, with access to the same data and ability to coordinate their objectives.

While there are many elements to this problem, the foundational JADO/JADC2 challenges can be generalized as a sensor-to-shooter kill chain, or battle network. A kill chain is a chain of systems that receive and process information about individual threats (sense), share and interpret information to assess the complete threat picture and its potential impact (make sense), and plan and execute effects against the threats (act). Increasingly, the defense community is extending this to the concept of a "kill web," in which many sense, make sense, and act elements can be flexibly employed in a mix-and-match approach based on mission needs. While this emerging concept increases resilience and warfighting capability, it also further increases the complexity of the decision making and information flow requirements, requiring greater up-front analysis to ensure effective employment.



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Assessing the effectiveness of AI, machine learning and algorithmic techniques

AI, machine learning, and other advanced algorithmic techniques play critical enabling roles in JADO and JADC2. Sense, make sense, and act each involve the processing of massive amounts of data on very rapid time scales, requiring algorithmic processing at multiple points in the kill chain to achieve the speed and scale necessary for conflict against an adversary with a large, well-equipped, and agile military force. While algorithms for AI, machine learning, or autonomy can add significant value to the operation of complex SoS such as JADO kill chains, their application requires a full understanding of the benefits, costs, and risks of their use. Algorithm development, refinement, and assessment depends on modeling the factors that drive dissimilar information across platforms with high fidelity, as these factors are likely to be correlated with mission execution in ways that can't easily be predicted from a simple statistical or parametric modeling of information exchange.

BAE Systems' VSoS testbed uses a true model-based systems engineering (MBSE) approach that combines physics-based simulations and standard Systems Modeling Language with a common data layer to support digital model analysis. This approach enables both static, traceable systems engineering, which links data requirements and specifications across digital models, ensuring that the results of the testbed can be reliably traced to the authoritative digital engineering designs of the systems being represented. It further allows dynamic, executable system analysis, in which dynamically executable digital engineering models that represent system logic and data processing play a direct role in real-time simulations that extend to the physical virtual simulations as well as the data layer. The VSoS testbed architecture allows additional simulators to be added rapidly when needed, digital models to be integrated when available, and facilitation of real-time data sharing to apply and support tradeoff analysis of advanced algorithms, such as data fusion and auto-routing AI, operating on representative data at relevant locations within the architecture.

The Scenario

Using the testbed, BAE Systems implemented a defensive counter air scenario. The approximately 15-minute unclassified notional scenario progressed through three phases until a strike assignment was designated on the incoming red bomber. The company obtained the results shown in the graphic after ten runs each, with and without autonomy used to optimize the placement of sensing assets.

In addition to the overall mission outcomes, BAE Systems can quantify the impact of autonomy on each of the stages through individual reductions in duration in the scenarios using autonomy. Both sense and act saw reductions of 20% and 16%, respectively. However, it was the make sense stage that showed the largest gains using autonomy, of nearly 73%.

While these results are only preliminary and representative, this approach demonstrates the feasibility and benefit of modeling complex JADC2 scenarios at the tactical data level in order to assess and trade AI/ML algorithms and their ability to support mission effectiveness.

For more information on the JADO/JADC2 testbed, please contact Matthew Crozier at **matthew.crozier@baesystems.com**.

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