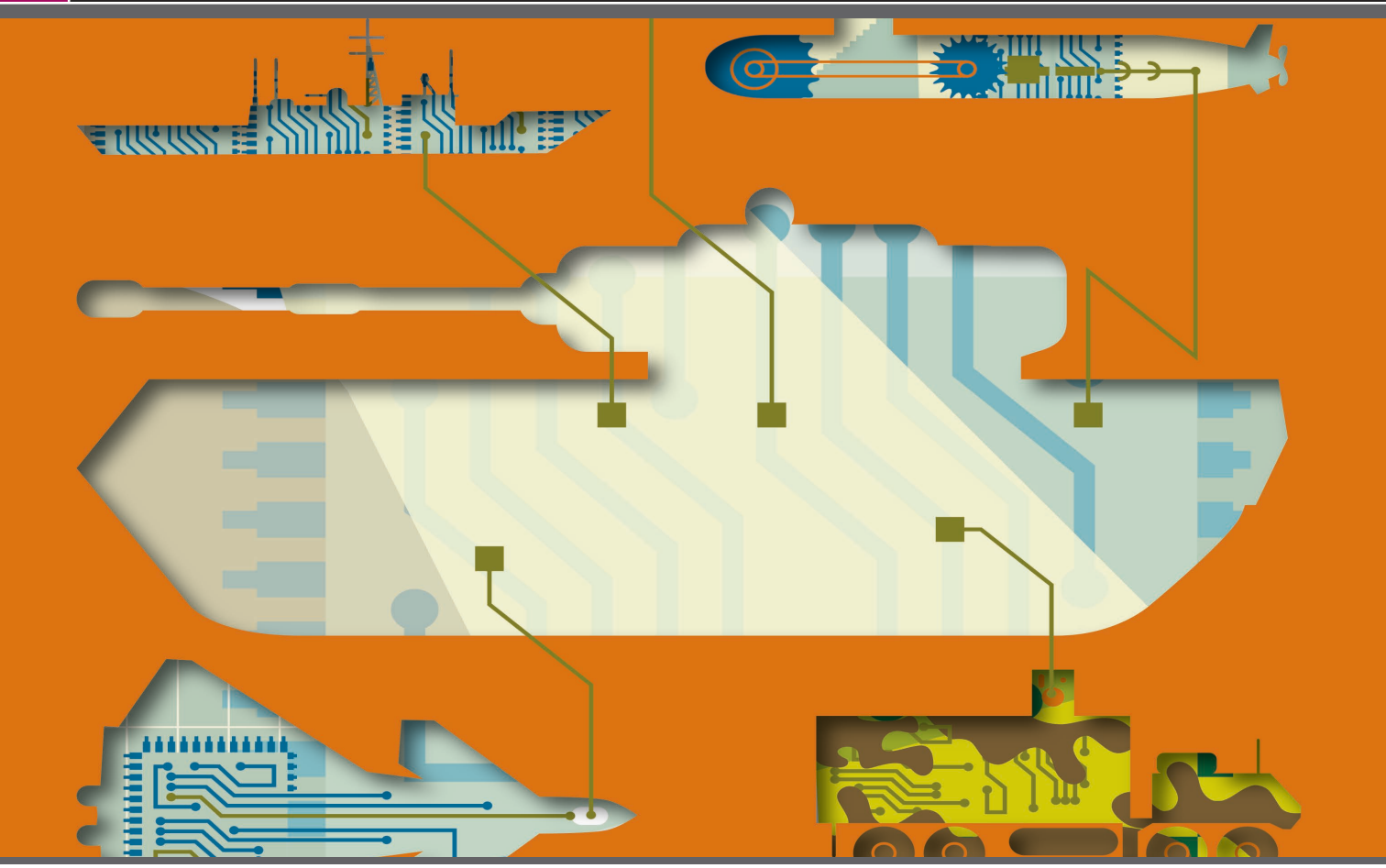

# CREATE: Acceptance and Adoption of Virtual Prototyping across the Defense R&D and Acquisition Communities

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The US Department of Defense (DoD), an enormously complex organization with an annual budget of nearly US$600 billion, is tasked with protecting the US and its allies and interests abroad against all potential adversaries. It must accomplish these tasks in a globalized and highly interconnected world where the pace of technology, especially defense systems, is moving faster than the current time-consuming DoD acquisition systems can keep up with. The rigid traditional acquisition timelines for researching, designing, producing, and operating state-of-the-art weapons systems is too slow, and the US is in danger of falling behind the technological advances of potential adversaries. Moving forward, the DoD must change these time-consuming paradigms and accelerate the pace of innovation. One way to do this is to shift to a faster, more robust, virtual prototyping environment where the benefits of high-performance supercomputing and complex physics-based engineering software can expand the decision space and enable the DoD to field better systems faster, cheaper, and at less risk than

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previous methods. This is the goal of the Computational Research and Engineering Acquisition Tools and Environments (CREATE) program.

This issue of *CiSE* provides the third installment of articles relating to the history, formation, and ongoing work of the High Performance Computing Modernization Program (HPCMP) CREATE program. Previous editions (January/February 2016 and November/December 2016) touched on the program's creation and described many of the various projects and software development initiatives that comprise it. This issue introduces four new articles that provide additional background and motivation for the CREATE program, as well as introducing the newest CREATE project, CREATE-GV (Ground Vehicles), followed by a technical discussion of CFD applications for the CREATE-Ships' NavyFOAM software development effort.

Although the CREATE program has been around for almost a decade, its genesis didn't come from the DoD. Rather, it was in recognition of the effectiveness of using virtual prototyping with high-performance computers by the US Department of Energy (DoE) that eventually made its way into private industry that provided the initial foundation for the CREATE program. "Product Innovation Through Computational Prototypes and Supercomputing" by Loren Miller explores the creation of the physics-based, virtual prototyping environment that was created at the Goodyear Tire & Rubber company in response to critical marketing challenges that could have crippled the company in the 1995 to 2005 timeframe. Miller provides a first-hand account of the many obstacles and institutional hurdles that had to be conquered before virtual prototyping changed the traditional design and production paradigm at Goodyear into a state-of-the-art responsive tire development enterprise that brought the company back from the edge of disaster. He provides a candid view of the difficulty in overcoming human nature's resistance to change, even in the face of a crisis, and what level of commitment is required for large organizations to incorporate such disruptive changes in their institutions. At the end of the day, it wasn't just the accuracy and expanded design space offered by physics-based virtual prototyping that created the environment for Goodyear to shift its research and production paradigm: it was the conviction of a cadre of designers, engineers, scientists, and their management who believed the benefits in time savings and more creative new products justified the cost and risk of conversion. An additional key factor in the acceptance and effectiveness of virtual prototyping for tire development at Goodyear was ensuring that the tire design tool supported the new tire development process and workflow.

Another key element for success that's apparent from the Goodyear paradigm shift experience was the need for meticulous verification, validation, and uncertainty quantification of leading-edge computational engineering codes. Without absolute confidence in the development and accuracy of these codes, any effort to create the conditions for institutional change are doomed. "Verification and Validation in CREATE Multiphysics HPC Software Applications" describes the approach taken to address the verification and validation (V&V) of the CREATE software products described in the earlier CREATE articles. It's based on the adoption of a set of V&V practices aligned with the recommendations of the National Academy of Sciences (NAS). The goal of these practices is to promote a test-driven development culture with the CREATE program. This article describes a practical approach to the implementation of the NAS guidance.

Although the original CREATE program in 2007 involved the creation of only four project areas (AV-aviation, Ships-ships and submarines, RF-antennas and radars, and a meshing and geometry [MG] capability to create virtual models), it was envisioned that the area of combat vehicle design and analysis would eventually be a viable expansion of the program's physics-based software development plan. In "HPCMP CREATE-GV: Supporting Ground Vehicle Acquisition," the ground vehicle project was formed in 2013 within the CREATE program to address this platform area. The GV project focuses on developing tools to simulate and analyze ground vehicle mobility. The objective is to establish physics-based, high-performance computing tools to enhance ground vehicle concept development, inform requirements development, and provide the requisite data for trade-space analysis. To facilitate this objective, the GV program is developing three software tools: Mercury, a physics-based tool used to conduct multiphysics simulations of terrain mechanics and vehicle systems and components; the Mobility Analysis Tool (MAT), a computational tool used to provide tactical mobility performance metric data; and a Ground Vehicle Interface (GVI), a user interface that provides a simplified and intuitive process to perform simulations using Mercury and MAT. These codes support trade-space and design

space exploration, as well as design analysis, with the goal of positively impacting cost, schedule, and performance with a significant reduction in design risk for the acquisition community.

The final article provides an in-depth look into the many facets of physics-based engineering software code development. In "A Scalable and Extensible Computational Fluid Dynamics Software Framework for Ship Hydrodynamics Applications, NavyFOAM," Sung-Eun Kim and colleagues at the Naval Surface Warfare Center Carderock Division discuss the many challenges facing simulation-based hydrodynamic design of naval ships, from the complexity of the salient physics involved around ships to the multidisciplinary nature of ship applications. Developing software that properly models the flow physics using "first principles" is computationally challenging, ranging from software architecture and V&V to quality assurance. The article presents a computational fluid dynamics (CFD) framework called NavyFOAM, which is one of four CREATE-Ships' physics-based software products. NavyFOAM has been built around OpenFOAM, an open source CFD library written in C++ that heavily draws on object-oriented programming. The design philosophy, features, and capabilities of the software framework and the computational approaches underlying NavyFOAM are described in the article, followed by a description of the V&V effort and application examples selected from the US Navy's recent R&D and acquisition programs.

As the CREATE program approaches its first decade of performance, many things have occurred along the way to herald its success. With growing acceptance and adoption of physics-based virtual prototyping as a viable and critical element in future DoD acquisition programs, there's much to look forward to as the program continues to provide new and expanded capabilities of its software products to meet the needs of its DoD customers. ■

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