The Computational Research and Engineering Acquisition Tools and Environments (CREATE) Program

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Physics-based high-performance computing (HPC) engineering software applications are proving highly effective for the development of complex innovative products such as automobiles, airplanes, and microprocessors. Over the next year and a half, *CiSE* will feature three issues describing the US Department of Defense (DoD) High Performance Computing Modernization Program (HPCMP) Computational Research and Engineering Acquisition Tools and Environments (CREATE) program. CREATE was launched in 2006 to develop and deploy a set of multiphysics HPC software applications to help the DoD acquisition community (government and industry) develop innovative military air vehicle, naval vessel, and radio frequency antenna systems.
CREATE Tools
Due to the exponential growth of the calculational power of high-performance computers from 100 floating-point operations per second (FLOP/s) at the end of World War II to more than $10^{16}$ FLOP/s today, it's now possible to accurately predict system performance such as aircraft controllability, ship survivability, and operating characteristics of multiple RF antenna systems embedded on military platforms such as airplanes. Similar tools have enabled the reduction of product development risk, cost, and schedule, and led to substantial increases in product innovation in industry and federal agencies such as the National Nuclear Security Agency (part of the Department of Energy).

Engineers can use these tools to generate virtual prototypes of real systems and analyze their performance to predict the performance of the real system. This can be done much earlier, more quickly, and more cheaply than is the case with the conventional product development process, which relies on live testing of the manufactured system to determine a given design’s performance. Live testing can only occur late in the design cycle, at a point where correcting design flaws can require extensive rework, increasing cost and schedule. The virtual prototype approach allows the identification of design flaws early enough that they can be fixed before manufacturing.

The CREATE program consists of nine software products:

- three codes for the design and analysis of military air vehicles, including DaVinci, a tool for generating and developing conceptual designs for military aircraft; Kestrel, a high-fidelity code for the design and analysis of fixed-wing air vehicles; and Helios, a high-fidelity code for the analysis and design of rotary-wing air vehicles;
- four codes for the design and analysis of naval vessels, including RSDE (Rapid Ship Design Environment), similar to DaVinci but for naval vessels; NavyFOAM, a high-fidelity code to assess the hydrodynamic performance of surface and underwater ships; NESM (Navy Enhanced Sierra Mechanics), a high-fidelity code for assessing shock vulnerability and live fire damage effects for naval vessels; and IHDE (Integrated Hydrodynamic Design Environment) for providing naval architects easy access to the Navy’s standard lower-fidelity hydrodynamic codes.
- the Radio Frequency high-fidelity code SENS TRI, which provides a highly accurate analysis capability based on “full wave” treatment of Maxwell’s equations; and
- Capstone, a CAD-neutral geometry and mesh tool that enables the creation of a digital model of the platform geometry with attributes.

Secure access to software over networks is a major challenge; many DoD engineers can only use a Windows PC with nothing more than MS Office and a browser. The software-as-a-service (SaaS) HPC Portal handles this by allowing authorized users with a browser to access HPCMP tools securely with two-factor authentication over an encrypted link, set up their problem, run it, store the results, and visualize them. The Portal has become an essential part of the CREATE tool box, with CREATE tools now being used by over 110 DoD acquisition organizations (government, industry, and academia) to analyze more than 70 different DoD systems.

In This Issue
This first of three special issues focuses on the challenges of developing and deploying complex multiphysics software designed to run on next-generation computer platforms. Although CiSE includes engineering in its title, relatively few CiSE articles address computational engineering issues. The development of engineering software presents different challenges than the development of software for scientific research. Much research software is written to support the research program of the code’s author. The author understands the code in detail, so there isn’t as much need for a rigorous design and development process nor for extensive documentation. If, on the other hand, the code is intended for use by engineers who didn’t write the code and don’t have the tacit knowledge that the code’s author possesses, the code must be much more robust and tested as well as much better documented. Validation, verification, ease of use, accuracy, and robustness are essential requirements.

This issue contains six articles, the first of which, “CREATE: Software Engineering Applications for the Design and Analysis of Air Vehicles, Naval Vessels, and Radio Frequency Antennas,” summarizes the CREATE program, its goals and challenges, the nine software products, the portal, the program’s organization and management, major software engineering practices, information assurance and intellectual property issues, and the
development approach that’s resulting in successful code adoption and support.

The second article, “A Fixed-Wing Aircraft Simulation Tool for Improving DoD Acquisition Efficiency,” describes the Kestrel code, outlining its highly flexible software architecture, the current physics capability (computational fluid dynamics, structural dynamics, flight control with external control surfaces, and propulsion), some examples of applications, and future planned capabilities.

The third article, “Capstone: A Geometry-Centric Platform to Enable Physics-Based Simulation and System Design,” describes the capability for generating a digital representation of the system geometry and making a mesh for use by analysis codes such as Kestrel. It lists different tools for supporting concept design and high-fidelity codes, and describes some representative examples of applications.

The fourth article, “A Risk-Based, Practice-Centered Approach to Project Management for HPCMP CREATE,” describes the practices that the CREATE program followed to achieve program success. The program sought to minimize the historic risks associated with developing complex, physics-based engineering software with distributed development teams in a large, complex organization such as the DoD. The major “lessons learned” are based on the authors’ extensive experience with such code development, the general software engineering literature, and discussions with their colleagues at Carnegie Mellon University’s Software Engineering Institute. These lessons learned were applied to the risks associated with the DoD to identify specific practices to minimize them. The key challenge was to implement a management structure that balanced the need for an agile management process with the need for sufficient accountability and organization in the development process to ensure that an annual release with the desired enhanced technical capabilities occurred.

The fifth article, “HPCMP CREATE-AV Quality Assurance: Lessons Learned by Validating and Supporting Computation-Based Engineering Software,” summarizes the CREATE Air Vehicles project’s software acceptance testing process. After the developers finish a new release, the code undergoes acceptance testing by an independent quality assurance (QA) group. Although the new release will already been through a rigorous validation and verification process by the development team, the independent QA group ensures that the code is ready for use by the general DoD acquisition engineering community. This independent review has been a major asset in achieving a high level of user satisfaction.

The last article, “Secure Web-Based Access for Productive Supercomputing,” describes the HPCMP Portal, which enables CREATE user communities secure collaboration without requiring user installation or configuration.

We’re planning to publish five more CREATE articles later this year and six in early 2017. The 2016 issue articles will cover the software engineering practices, verification and validation, and uncertainty and quantification practices employed by the CREATE code team; NavyFoam; Helios; RSDE; and SENTRi. The 2017 issue will feature six more codes including the NEM code, a new version of NavyFoam with a “strand” meshing capability that should be more accurate, IHDE, DaVinci, a description of a set of tools for designing and assessing military ground vehicles, and a case study of the impact of the use of virtual prototypes for a major industry.

References

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Selected articles and columns from IEEE Computer Society publications are also available for free at [http://ComputingNow.computer.org](http://ComputingNow.computer.org).

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