High Performance Computing Policy Paper

National Research Council Workshop - Brainstorm HPCD
Todd Simons
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Introduction

Rolls-Royce welcomes the opportunity to provide input on the National Research Council's recommendations on computing infrastructure at the Brainstorm HPCD Workshop. As a leading engineering and high-technology manufacturing aerospace company, we have significant experience in bringing innovative research and new technology into high value products and services. This experience has taught us that to deploy advanced technologies and to compete effectively in a global industry requires partnerships with our suppliers, academia and government.

Research Needs/Opportunities

Gas turbine engine design relies increasingly on large-scale modelling and simulation. Staying at the forefront of large-scale simulation is vital to achieve better understanding for the science and physics required to manufacture competitive products. Aerospace companies face the challenge of balancing the requirements of adding new capabilities in existing software with updating software for new computing platforms and for greater scalability. Advanced analysis is required in aerodynamics, heat transfer, and mechanical structures. Improved modelling and simulation help deliver higher efficiency, lower emissions and reduced time to market. Close collaboration between universities, national computing centers and software vendors are needed to address the challenges facing the manufacturing industry to provide competitive products.

Among the challenges facing industry are adapting codes to massively parallel platforms to improve the fidelity of the physics and to perform calculations that capture transient phenomena quickly enough to impact design cycles. This requires scaling up the entire workflow including pre- and post-processing, not just the core physics solvers. Validation requires significant effort, but remains an important step to guarantee accurate results. Uncertainty quantification (UQ) is another important aspect of modelling and simulation. UQ provides designers with insight into the source of inaccuracies and connect the manufacturing process with simulation. Because of this it is important for the National Science Foundation to include software transformation and software development as a key priority for future funding.

While many aerospace companies have proprietary computational fluid dynamics (CFD) codes, there are only a few widely adopted turbulence models. Turbulence modelling in compressible (CFD) applications is an open problem that is both computationally and data intensive. Accurate modelling of transient physics in off-design conditions for gas turbine engines remains a significant challenge (NASA/CR-2014-218178).

The scalability of commercial codes also remains a challenge for industry, particularly for Finite element modelling (FEM) codes. Good progress has been made by LS-DYNA, Star-CD, and ANSYS, but more support from national computing centers will benefit advanced manufacturers and their supply chain. In particular, collaboration between industry, (expand ISV) ISVs, and national computing centers is needed to improve real world modelling and simulation capabilities that will benefit society.

Advanced Computing Capabilities, Facilities, Requirements

Rolls-Royce makes use of both commercial and proprietary software in the design of gas-turbine engines. Proprietary CFD flow solvers prevail in the aerospace community, while Commercial Windows and Linux based software is used for geometry specification (solid modeling software), grid generation, and post-processing. Finite element modelling (FEM) used for computational structural mechanics is done primarily with commercial software with proprietary customization. Workflows in the design environment must accommodate both current and legacy software for different levels of fidelity, from preliminary design to detailed component design.

In addition to the growing size of modelling and simulation data sets, engine health monitoring (EHM) allows companies to collect large amounts of information per flight on existing engine fleets. There is significant potential to use predictive analytics to improve safety and reduce support costs. This data is quite sensitive, not just from an intellectual property perspective, but the data is export controlled. Because fleet information on military aircraft can indicate vulnerabilities or can reveal tactics or troop movements, the government may treat this information as classified information requiring security clearances to access. The cybersecurity aspect of this data complicates the ability to collaborate. Gas turbine engines are export controlled and there is currently no cloud computing solution that satisfies current ITAR export control regulations.

The adoption of GPUs, the Xeon Phi and customized processors add complexity in both software development and procurement of hardware. Hardware purchases need to accommodate the existing code base and legacy software. In particular, advances in low power computing will reduce operating costs and reduce the environmental impact of modelling and simulation.

Challenges and Suggestions

Industry in most cases cannot make leading investments in high performance computing (HPC) and will benefit from cost-effective access to national or academic HPC infrastructure for research purposes. Allocations to industry are needed for the research and development not only to provide help in scaling existing codes, but to develop and validate methodologies for modeling complex unsteady physics. Understanding complex unsteady physics leads to design innovations. In additional to scaling the unsteady modelling and simulation codes, support through allocations is needed for validating these techniques before this can be used in the design process. Industrial allocations are needed to support this type of work to bring technology from low technology readiness levels (TRL) to a point where they can be used in design.