White Paper

To Out-compute is to Out-compete: Competitive Threats and Opportunities Relative to U.S. Government HPC Leadership

Sponsored by: Dell Technologies and AMD

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HYPERION RESEARCH OPINION

Nations and companies have learned that to be competitive in global innovation, advancing science and R&D requires serious computing capabilities. For more than three decades the US Council on Competitiveness has brought together a broad spectrum of constituents to champion an agenda that fuels entrepreneurship and spurs the commercialization of new ideas. It coined the term "To Out-compute is to Out-compete" as a way of describing the need for advanced computing capabilities. This paper takes that sentiment and examines U.S. government investment in high performance computing (HPC) across its various departments and agencies.

Investments in HPC are recognized globally as a fundamental tool for conducting R&D and advancing the economic competitiveness of nations. More countries than ever are increasing their spending on HPC infrastructure and critical associated areas, including AI, applications development and optimization, and workforce development and retention. Nations who do not adequately invest in HPC infrastructure and workforce development run the very real risk of weakening their national defense and falling behind economically.

National investments in HPC are not just academic exercises. Hyperion Research studies have shown return on investment is very high and can reach $507 dollars in sales revenues per dollar invested in HPC, and $47 dollars in profits or cost savings per dollar invested in dedicated strategic HPC activities.

Returns relative to national security go well beyond national military defense. Advances by medical researchers working in disease detection, prevention, and cures in the interest of public health require access to HPC infrastructure. Scientists working on digital twins of the earth to supplement existing climate and weather modeling to protect public welfare rely on advanced technical computing. Engineers performing complex modelling and simulation depend on advanced computing to develop more fuel-efficient and aerodynamic cars and planes.

Government leadership relative to investing in HPC infrastructure is critical. While the US government is making large investments in leadership-class machines (e.g., Frontier at ORNL, El Capitan at LLNL, and Aurora at ANL), it is at risk of falling behind in maintaining and extending its HPC investments to address the next tier of divisional and departmental requirements. Through increased investments in HPC, many U.S. government departments and agencies can bolster their missions and deliver outcomes benefiting all. Failure to make these investments not only jeopardize missions, but could compromise the defense, health, and overall well-being of the entire nation.

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EXECUTIVE SUMMARY

Why Nations are Investing More in HPC

High performance computing (oftentimes referred to as supercomputing) has made enormous contributions to national and global scientific, engineering, and industrial competitiveness, as well as to homeland security and other government missions, since its introduction in the 1960s.

Supercomputers have played crucial roles in numerous government agencies and departments. Their impact, however, goes far beyond that. Supercomputers have made cars and planes much safer, more fuel efficient and environmentally friendly. They are crucial aids in discovering and extracting new sources of oil and gas, and for developing alternative energy sources. They have enabled the weather community to create more accurate predictions of severe storms that can devastate lives and property. Industries ranging from financial services to medicine and health care, entertainment, consumer products, and more recently by Internet companies and cloud service providers rely heavily on HPC. They have helped mankind explore space and understand how the universe was formed.

The ROI from Investing More Heavily in HPC and R&D is Very Strong

HPC-based computer simulation has become a fundamental driver of scientific discovery in many disciplines and is often referred to as the "third pillar" of scientific discovery, complementing traditional theory and experimentation. Supercomputers are a tool for researching scientific areas in ways that were previously impossible to pursue. HPC typically allows for dramatically faster time-to-solution and time-to-discovery. Scientific and industrial organizations often find it difficult to quantify their returns from using HPC, yet some things are clear:

- A growing number of Nobel laureates have relied heavily on HPC for their achievements.
- In academia, HPC use has spread from its established strongholds in the physical sciences to the social sciences and the humanities.
- HPC use has repeatedly saved lives and property by predicting severe storms.
- In the automotive and aerospace industries, HPC has dramatically reduced the time-to-market and increased the safety and reliability of new vehicle designs.
- Some large industrial firms have cited savings of $50 billion or more from HPC usage.
- HPC has allowed the modeling of phenomena that are impossible or undesirable to test (e.g., nuclear accidents).

Hyperion Research has been tracking the ROI from investments in HPC since 2013 as part of a US Department of Energy (DOE) grant. The industrial returns from successfully applying HPC to industrial problems in this study have been large:

- Industrial firms have seen sales revenue returns of $452 for each dollar invested in HPC.
- Finance, manufacturing, life sciences, and transportation realized:
  - $504 sales revenue returns for each dollar invested in HPC.
  - $38 in profits or cost savings for each dollar invested in HPC.

Details on the study, including input data, summary slide deck, success stories and the full report can be found on the HPC User Forum website (www.hpcuserforum.com).

The U.S. HPC Sector: Accelerated by U.S. Government Involvement

For more than fifty years, the United States has led the world in the development, supply, and use of HPC. This capability was due in large part to a comprehensive program of sustained federal government investments in HPC-related R&D, targeted procurements of systems at the highest level of performance, and perhaps most important, a broad and continued partnership with U.S. HPC commercial vendors. The U.S. Government (USG) recognized early on that to meet its broad range of important science, engineering, and defense applications, it had to help foster a robust, secure, domestic supply of the most powerful systems in the world. The successful partnership between the U.S. government R&D community and its domestic HPC supply base has served as a model that has been replicated, albeit to a somewhat lesser extent, throughout the world. While this has served the U.S. government well relative to leadership class machines, there's more work to do.

Beyond HPC Leadership Class Machines

Leadership class machines receive a large amount of media attention due to the increasingly large price tags and impressive benchmarks they can deliver. However, many of the challenges scientists and engineers are faced with today don't require the full capabilities of leadership class machines (those that cost over $500K). Divisional (costing $250K to $500K) and departmental (costing $100K to $250K) class machines can often satisfy the demands of a broad array of scientific, engineering, AI, and (high performance data analysis) HPDA workloads. According to recent Hyperion Research studies, the divisional and departmental class machines comprised 43.7% of the market in 2021.

Requirements, designs, and procurements for leadership-class machines are driven largely by the DOE and several NSF-funded academic sites (e.g., TACC). Many other US government departments and agencies are constantly examining their current HPC infrastructure and future HPC resource needs to ensure they can continue to properly support the increasing demands workloads are placing on the systems. A small subset of these departments and agencies include:

- Department of Defense (DOD)
- Department of Homeland Security (DHS)
- Federal Bureau of Investigation (FBI)
- Intelligence Advanced Research Projects Activity (IARPA)
- National Aeronautics and Space Administration (NASA)
- National Institutes of Health (NIH)
- National Oceanic and Atmospheric Administration (NOAA)

Rapidly Evolving Innovations and Heterogeneity in HPC Ecosystem

Suppliers are responding to HPC users' increasingly demanding and complex requirements with a growing array of novel innovations across the ecosystem, including:

- New types of CPUs and general-purpose processors (e.g., AMD EPYC)
- Accelerators and special-purpose processors (e.g., AMD Instinct)
- Memory and storage convergence
- System design divergence to support a broader set of applications
- HPC resource access models

Increased investments in current technologies and innovations are required for departments and agencies to deliver on their missions. Those that fail to do so run the risk of failing to fully fulfill their missions and deliver on their committed outcomes.

HPC SOLUTIONS AND DELL TECHNOLOGIES

Navigating today's HPC ecosystem is no small task. A proper balance of performance, scale, applications, and support is required to provide users and their data center managers the appropriate infrastructure to satisfy their needs. Users need to partner with vendors with a diverse range of products, services, and support offerings who deeply understand user requirements.

With several systems in the Top20 of the Top500 list, Dell Technologies in an example of an HPC supplier that takes lessons-learned from leading HPC systems, applies them to solutions with broader HPC market appeal, and augments them with corresponding support and choices of access methods:

- **Dell PowerEdge Servers:** With a broad array of servers from which to choose, including the R6515 and R7515 based on the 3rd Gen AMD EPYC processor, Dell has an HPC node to satisfy whatever scale users' workloads demand.
- **Dell Technologies on Demand:** The cloud is increasingly being adopted as an HPC resource incremental to on-premises infrastructure. Dell partners with leading CSPs to offer HPC cloud-based solutions to support customers with cloud-native, hybrid-cloud, and multi-cloud applications.
- **HPC & AI Innovation Lab:** This team of engineers and subject matter experts collaborates with customers and partners to move beyond individual products and develop targeted solutions HPC & AI workloads. The Lab is available for customers to evaluate new technology or develop focused solutions for a specific outcome, or virtually via access on-line resources for best practices and benchmark results.
- **Customer Solution Centers:** Resourced with Dell personnel, these centers provide customer and partners free hands-on access to Dell infrastructure and the opportunity to interact directly with Dell for demos and testing before buying. Interaction with the HPC & AI Innovation Lab for advanced solution engineering and performance testing is also available through these centers.
- **HPC & AI Centers of Excellence:** With almost a dozen locations around the world, these third-party centers develop and maintain local partnerships, test new technologies, share best practices and function as entry-points for customers to provide feedback and influence future product roadmaps.
- **Dell HPC Community:** Pre-COVID-19, Dell facilitated several in-person gatherings throughout the year for worldwide community networking and collaboration. Successfully evolving this to an on-line virtual activity, the Dell HPC Community event is a vibrant weekly gathering led by a combination of industry subject matter experts and Dell HPC experts to provide insight and education across a wide variety of HPC topics.