White Paper Series - 3 of 4

To Out-compute is to Out-compete: In the Interests of National Security - Defense Technologies and Use Cases

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HYPERION RESEARCH OPINION

When high performance computing is used in the same sentence as national security, thoughts typically turn towards military, defense and homeland security. The National Nuclear Safety Administration (NNSA) section of the Department of Energy (DOE), with its charter of providing stewardship of the U.S. nuclear stockpile, has frequently found itself at or near the top of the Top500 list as a site hosting the world's most powerful supercomputers. The Department of Defense (DoD) has employed HPC infrastructure directly at its various branches' research labs (e.g., Naval Research Lab [NRL], Army Research Lab [ARL], Air Force Research Lab [AFRL]), as well as within the Defense Advanced Research Projects Agency (DARPA), to develop branch-specific defense weaponry and to perform detailed weather modeling across various operating theaters. The DoD has also greatly benefited indirectly from the many government subcontractors' application of HPC in the design and development of a wide array of military equipment, including fighter jets, submarines, weaponry, and data analytics supporting its warfighters.

However, in addition to these military applications and operations, there are other use cases that rely on advanced technologies such as HPC to meet their overall mission requirements. A sampling of these areas includes:

- Intelligence community and cybersecurity
- Space safety and stewardship
- Global and local climate and weather modeling and
- Homeland and border security

While most governmental entities rely on HPC to meet their most critical mission requirements, more can be done. Bad actors around the world continue to find creative ways to leverage the latest technologies to defeat security systems. Threats are increasing from global adversaries that are heavily investing in the latest advanced technologies, including AI and quantum computing. To maintain a healthy balance to counteract increasing foreign capabilities, the U.S. government will need, at a minimum, an equal level of investment in these key areas.

Vendor consolidation in HPC has greatly reduced the options for these critical purchases. Dell Technologies, with its broad product and services portfolio, in conjunction with its technology providers, such as AMD, is working hard to develop solutions to address these critical national requirements.

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EXECUTIVE SUMMARY

National Security Beyond Military Defense

While military defense and border security are critical to the national security of the U.S., other facets play key roles as well. Some of these facets include:

- Intelligence, and border protection
  - Intelligence
  - Cybersecurity (offensive & defensive)
  - Imaging and sensing analysis
  - Space monitoring and stewardship (e.g., space debris, space defense)
  - Homeland security and border security (e.g., coast guard, FBI, re-entry into country & visualization; no-fly list; image recognition)
- Public health and safety
  - Public health
  - Emergency and crisis response
  - Sustainability
  - Weather and climate
- Commerce and finance
  - Anticipation of and responding to economic downturns
  - Global supply chain
  - Counterfeiting and financial security
  - Infrastructure (e.g., smart cities, national power grid)
  - Indigenous technology impacting US companies
  - Educated workforce

Each facet of national security is worthy of further exploration. This paper will focus on the physical security aspects of national security.

MARKET OPPORTUNITY FOR HPC IN THE INTERESTS OF NATIONAL DEFENSE

In addition to serving the public in contributing to the national defense, vendors who can provide the necessary solutions and support to the various government departments and agencies chartered with that mission can achieve significant economic returns. Table 1 summarizes the U.S. technical server market opportunity by sector, including the various verticals and applications comprising the government sector.

TABLE 1

U.S. High-Performance Technical Server Revenue by Sector ($M)

	2021	2022	2023	2024	2025	2026	CAGR 21-26
Government	$2,109	$2,629	$2,873	$3,156	$3,175	$3,327	9.5%
Defense	$833	$912	$997	$1,095	$1,101	$1,154	6.7%
National Labs	$751	$1,142	$1,248	$1,370	$1,379	$1,444	14.0%
Weather	$310	$343	$374	$412	$414	$434	6.9%
Bioscience	$143	$155	$169	$186	$187	$196	6.5%
CAE	$72	$78	$85	$93	$94	$98	6.5%
Industry	$3,122	$3,363	$3,674	$4,037	$4,061	$4,255	6.4%
Academia	$779	$908	$993	$1,090	$1,097	$1,149	8.1%
Total	$6,009	$6,900	$7,540	$8,284	$8,333	$8,731	7.8%

Note: The lightly shaded rows are application areas within the government sector that utilize HPC. They sum to the Government total.

Note: The Weather, Bioscience, and CAE include only the government component of those respective verticals.

Source: Hyperion Research, July 2022

Table 1 includes only the technical server element of an HPC solution. Technical servers make up roughly 50% of the overall HPC market opportunity. After incorporating the other broad market elements of an HPC solution (storage, middleware, applications, and service), the total U.S. HPC market in 2021 was approximately $12.5B and is projected to grow at a 5-year CAGR of 6.7%, expecting to reach over $17B in 2026. The total U.S. HPC market by broader market area is reflected in Table 2.

TABLE 2

U.S. HPC Forecast by the Broader HPC Market Areas ($M)

	2021	2022	2023	2024	2025	2026	CAGR 21-26
Server	$6,009	$6,900	$7,540	$8,284	$8,333	$8,731	7.80%
Storage	$2,596	$3,023	$3,317	$3,659	$3,700	$3,894	8.50%
Middleware	$735	$812	$854	$903	$873	$906	4.30%
Applications	$2,165	$2,428	$2,591	$2,780	$2,729	$2,855	5.70%
Service	$1,012	$1,046	$1,027	$1,014	$915	$908	-2.10%
Total Revenue	$12,517	$14,209	$15,330	$16,640	$16,551	$17,294	6.70%

Source: Hyperion Research, July 2022

Varying Requirements for Different Aspects of National Defense and Security

The DOE's national labs garner a lion's share of the media and technical community's attention relative to HPC due to the extreme scale of performance capabilities and dollars spent on their leadership-class machines. Frontier, the most recently installed DOE supercomputer at the Oak Ridge National Lab (ORNL) and holder of the current top spot on the Top500 list, cost upwards of $600M for the supercomputer itself (e.g., not including required infrastructure investments to support its power, cooling, and weight requirements). But not all national defense and security-related HPC workloads require such scale of machines. Many applications and workloads require less capabilities than the leadership-class supercomputers provide. Roughly half of the U.S. market for technical servers are for systems that cost less than $500K USD. Table 2 provides a Competitive Segment view of the U.S. technical server market. HPC infrastructure utilized in the defense sector is likely to scale in the same fashion.

TABLE 3

U.S. Technical Server Market Revenue Forecast by Competitive Segments ($M)

	2021	2022	2023	2024	2025	2026	CAGR 21-26
Supercomputer (Over $500K)	$2,574	$3,097	$3,415	$3,805	$3,848	$4,095	9.7%
Divisional ($250K to $500K)	$1,297	$1,446	$1,580	$1,744	$1,808	$1,868	7.6%
Departmental ($100K to $250K)	$1,566	$1,772	$1,929	$2,083	$2,046	$2,183	6.9%
Workgroup (Under $100K)	$572	$584	$615	$652	$631	$585	0.4%
Total	$6,009	$6,900	$7,540	$8,284	$8,333	$8,731	7.8%

Source: Hyperion Research, July 2022

Threats and Opportunities

Despite possessing the top spot on the current Top500 list, all is not well across the broad spectrum of U.S. government investment in HPC. China quietly installed two similar sized systems a year ago and is aggressively pursuing technologies in HPC, AI and quantum computing for defense applications. European weather models are generally accepted to be better at predicting the magnitude and path of U.S. hurricanes much sooner than current U.S.-based models. Singapore is recognized as being the current global leader in understanding and advancing smart city research and applications.

There is no specific root cause of these deficiencies, but major growth in purchases is required to keep pace. That said, a combination of delayed upgrades to hardware infrastructure and postponed efforts to modernize application codes are likely contributing factors.

HPC Solutions and Dell Technologies

TOP500 HPC systems aren't required to address all of the HPC applications and workloads required by the various U.S. government agencies tasked with providing for all aspects of the nation's physical defenses. Many of these workloads can be run on smaller HPC clusters of comprised of less expensive and less experimental hardware infrastructure that many enterprise IT datacenters already employ.

Dell Technologies is a leading provider of enterprise IT solutions across a broad range of IT infrastructure categories (e.g., servers, converged, hyperconverged, storage, and AI). Within the HPC market, Dell Technologies is the second leading provider of HPC technical servers globally with a 21.8% on-premises market share, and the most preferred HPC storage vendor, being deployed at

more than 18% of HPC sites in 2021, according to Hyperion Research market studies. Coupling their industry enterprise IT expertise with their HPC technologies and solutions makes Dell a great partner for both industry and the U.S. government to support its efforts to grow the country's industrial economic competitiveness and provide for the nation's defense. Dell's strong portfolio of HPC products and solutions, augmented with corresponding support and choices of access methods, includes:

- **Dell PowerEdge Servers:** With a broad array of servers from which to choose, including the R7525 and C6525 based on the AMD™ EPYC processor, Dell has an HPC node to satisfy whatever scale users' workloads demand.
- **HPC On Demand:** The cloud is increasingly being adopted as an HPC resource incremental to on-premises infrastructure. Dell partners with leading CSPs, automation vendors, and managed service providers to offer HPC cloud-based solutions to support customers with cloud-native, hybrid-cloud, and multi-cloud applications.
- **APEX Flex on Demand:** While some HPC workloads are being migrated to the cloud, there is still demand for on-premises or co-located HPC infrastructure. On-premises users do, however, recognize the advantages of a cloud-like business model based on OPEX and a pay-as-you-go approach, as opposed to a CAPEX-heavy investment model. APEX provides users with a flexible approach to gain access to on-premises HPC resources with subscription pricing.
- **Cybersecurity Solutions:** Addressing challenges such as data backup and recovery, threat vulnerability detection and response, supply chain integrity, and managing 24x7 security operations, Dell provides a wide range of solutions for managing the increasing cybersecurity-related threats and breaches. Providing cyber resilient security relative to protecting, detecting, and recovery, Dell's PowerEdge servers extensive use of intelligence and automation helps you stay ahead of the threat curve, and to enable the scaling demanded by ever-expanding usage models.
- **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 and now re-establishing as the world emerges from 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.

Providing for the National Defense

Providing for the national defense of the U.S. is a complex undertaking. A diverse range of governmental departments and agencies have either in part, or in whole, national defense or homeland security as their mission. Overlap may exist across U.S. government organizations' missions that are focused on the different areas of physical security (e.g., military defense and operations, intelligence, cybersecurity, space, and homeland/border).

Military Defense and Operations

HPC infrastructure is critical in providing for the most timely and accurate information required to support the best decision-making for military defense and operations. Each area of military defense and operations may also drive different requirements for the type of information that drives each area's decision-making. A small sampling of these diverse areas include:

Tactical Weather Forecasting

The success or failure of many on-field military engagements may be highly dependent on weather conditions. Air campaigns' success are affected by visibility conditions. The timing of sea-based engagements may be dependent on the tides. Land-based campaigns are impacted by the type and amount of expected precipitation. The quality of data in each of these areas (e.g., accuracy of the predications, lead-time for accurate information) is highly dependent on the performance of the HPC infrastructure and quality of the weather and meteorological modeling software.

Each branch of the DoD (e.g., Army Research Lab [ARL], Nav Research Lab [NRL], Air Force Research Lab [AFRL]) employs their own modeling infrastructure. NASA, NOAA, and NCAR all also contribute related weather modeling and analysis in support of the nation's defense.

Logistic, Maintenance, and Control

This area may represent a large untapped source of computational demand to help drive and optimize decision-making. Identifying all aspects related to various resources (e.g., personnel, equipment, fuel) is critical for strategic placement of the resources, along with optimizing associated costs. Various aspects to understand include:

- Tracking current location and quantity of the resource
- Predicting amount of and where the resource will need to be
- Identifying resource replenishment timing and strategies and
- Addressing supply chain issues

One particularly critical area of simulation that drives requirements for the most critical HPC systems is the area of nuclear weapons stewardship. For example, HPC clusters employed by the National Nuclear Safety Administration (NNSA) branch of the DOE often run jobs that require more than half of their largest systems. Many sites run jobs that can require a major portion of their system for multiple years. One example of a large multi-year job is to determine when nuclear submarines should be cycled through for maintenance and upgrades of their ordinance and payloads.

Surveillance and In-theater Image Recognition

Real-time identification of high-value targets (HVT) drives a unique set of requirements for AI and HPC systems. Warfighters capture real-time video of on-going operations and provide that data for comparison against an in-theater database for real-time confirmation of HVTs. The increasing use of drones and unmanned aerial vehicles (UAVs) drive similar requirements. Satellites generate a massive number of images. The real-time computational capabilities required to provide the necessary support of real-time command and control decisions demand increasing investment and innovation across all areas of HPC, including AI, networking, cloud, and software.

Intelligence

The various U.S. Government intelligence communities all drive additional unique HPC-related requirements. Some examples of these include:

Real-time Monitoring of Social Media

While at times controversial, social media can be a rich source for intelligence gathering. Having the ability to monitor and identify real-time public reaction and observations to on-going events can inform next responses. System requirements to capture, analyze, inform, and store the almost infinite sources of social media inputs demands continuous innovation for HPC and AI infrastructures.

Big Data Analysis

Signal intelligence is another security area requiring extreme computational and analysis capabilities. Monitoring and deciphering the myriad amounts of satellite communication intercepts and separating valid transmissions from dangerous communications is a key discipline requiring the utmost performance and accuracy.

Data Encryption/Decryption

Many intercepted signals are likely to be encrypted. Applying the most advanced algorithms on the most powerful infrastructure allows analysts to provide timely intelligence to leadership for them to provide guidance and decisions in the field.

Cybersecurity

Cybersecurity has emerged as one of the more crucial areas for the national defense, requiring investments and innovation in new technologies such as quantum computing. Proper application of advanced cybersecurity techniques can be leveraged for both defensive and offensive purposes.

Defensively, deployment of advanced cybersecurity algorithms that can both detect and protect against state-sponsored cyberattacks on key national infrastructure is critical. Key infrastructure requiring this level of defense includes dams, the power grid, and military installations, including key command and control points.

Offensively, application of cyber measures could help deter and cripple infrastructure of known threats from adversarial states.

Space

Application of computational and AI capabilities for space-related innovation goes well beyond the relatively new Space Force branch of the DoD. NASA, the National Geospatial Intelligence Agency

(NGIA), and the National Reconnaissance Office (NRO) are a few of the agencies and departments requiring these capabilities. Some applications include:

Space Command Processing

Requirements for advanced computing and AI capabilities are growing across multiple space-flight processing applications. Satellites represent one of the most extreme edge points for the capture and initial processing of signal and imagery data. Both unmanned and manned spacecraft are also demanding computing infrastructure requiring the lowest levels of power consumption and smallest footprints in both size and weight to optimize fuel efficiencies.

Vehicle Design, Test, and Simulation

Traditional HPC modelling and simulation continue to demand increases in performance capabilities. Ranging from the aerodynamic design of the spacecraft to developing new, efficient rockets and rocket fuels, leveraging physics-based advanced computing hardware and software provides the ability for faster transport times for astronauts, reaching farther distances for manned spaceflight, and more sustainable power systems for transport.

Monitoring and Tracking Active Satellites and Space Debris

As more nations develop the capability to launch and utilize satellites, not only are there a growing number of satellites orbiting the earth, but there is also an increasing amount of space debris being generated. Utilization of advanced computing and AI techniques can help identify and track orbital paths of healthy satellites as well as the trajectories of material with decaying orbits, predicting when and where they may re-enter earth's atmosphere and present potential danger of reaching the surface.

Deep Space Exploration

At first considered by many as extreme science, deep space exploration could potentially have national (and global) defense and security implications. Identifying, tracking, and projecting paths of comets, meteors, and asteroids command advanced HPC compute and storage-scale capabilities. Programs such the Square Kilometer Array (SKA), Hubble telescope, and James Webb telescope create massive amounts of data that needs to be captured, processed, transferred, analyzed, shared and stored. Accurate models highly dependent on data generated from these efforts can provide early warning and enable efforts to mitigate or eliminate potential collisions and interference with key space-based infrastructure.

Homeland and Border Security

Monitoring the country's entry points for bad actors and advanced portable weaponry is an on-going concern. The number of entry points into the U.S. is vast (numbers are approximate):

- Over 6,000 miles of land border and more than 2,000 miles of coastal borders
- 150 international airports support over 45 million international arrivals in 2021
- 920 shipping ports supporting over 95% of U.S. overseas trade

Advanced HPC and AI-related systems (either on-premises or cloud-based) are more than capable of being employed for a broad range of use cases, including:

Facial recognition and real-time identification

Real-time capture of passenger facial features and comparison against threats and HVT database is crucial to denying entry of known or likely individual human threats. High-resolution imagery, big data analysis of the images at the edge detection points, and high-performance storage capacity of those images are a snapshot of the requirements driving next-generation HPC and AI capabilities.

General Image Recognition

Beyond identification of human threats, applications of HPC, AI, and Big Data techniques can also be applied to physical objects. The Transportation Safety Administration (TSA) could more quickly identify threats and process passengers more quickly through airports with advanced computational and big data analysis. Similar techniques could also be applied at a much larger scale with containers being offloaded (or before offloading) from cargo ships at the nation's ports.

FUTURE OUTLOOK

Investments in HPC will be critical in providing for the nation's physical defense. HPC solutions are utilized to support a diverse range of areas, including:

- Military defense and operations
- Intelligence community and cybersecurity
- Space safety and stewardship
- Global and local climate and weather modeling and
- Homeland and border security

Failure of the various U.S. departments and agencies tasked with providing for the nation's physical defense to modernize lagging hardware infrastructures and aging application codes could result in disastrous consequences for the country. Adversarial nations are investing heavily in new technologies and capabilities. They are trying to produce weaponry and systems that the U.S. is incapable of defending against. Bad actors could launch unprecedented cyberattacks against various U.S. military and defense infrastructure undetected.

The U.S. DOE currently possesses the top spot on the TOP500 list at ORNL. If the U.S. can direct equal attention and resources toward the broader aspects of the country's physical security that don't require the scale of leadership machines, much of the aforementioned risks and consequences may be averted or greatly reduced.

In the past, the U.S. government has demonstrated the resolve to invest in these resources and will likely continue to do so. It needs multiple, viable partners to provide state-of-the-art HPC solutions that meet the various departments' and agencies' requirements, particularly those that are strong in the divisional and departmental competitive segments of the HPC market. Dell Technologies, independently and in conjunction with technology partners such as AMD, is one example of such a potential partner. With industry leadership across a significant portion of the enterprise IT infrastructure categories, being a top leader in both HPC technical server and storage system markets and supporting the various business delivery models and support levels demanded by HPC users, Dell Technologies is well-positioned to support the U.S. government in its critical mission of providing for the nation's defense.

About Hyperion Research, LLC

Hyperion Research provides data-driven research, analysis and recommendations for technologies, applications, and markets in high performance computing and emerging technology areas to help organizations worldwide make effective decisions and seize growth opportunities. Research includes market sizing and forecasting, share tracking, segmentation, technology and related trend analysis, and both user & vendor analysis for multi-user technical server technology used for HPC and HPDA (high performance data analysis). Hyperion Research provides thought leadership and practical guidance for users, vendors and other members of the HPC community by focusing on key market and technology trends across government, industry, commerce, and academia.

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