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Operational Energy Solutions for a 21st Century Battlefield

Nestor Levin

Development of alternative energy storage and distribution capacity for the modern battlefield is a major national security interest.

In 2022, the world has become increasingly multipolar. The technological, military, and economic gap between the United States and its competitors is shrinking. According to a 2017 CNA Military Advisory Board report on Advanced Energy and U.S. National Security, "a U.S. energy stance centered on fossil fuels should not delay our … investment in advanced energy systems at home and abroad."[1] The DoD is the single largest energy consumer in the US and world's largest petroleum consumer.[2]

Such overreliance on hydrocarbon-based energy sources introduces threat vectors on the tactical, operational, and strategic levels. The massive American military apparatus dangerously relies heavily on extensive networks of logistics and infrastructure to supply oil and petrol. If the DoD moves away from hydrocarbon overreliance and instead adopts advanced energy systems while sponsoring their development and procurement, namely in batteries and micro grids, it will be in position to act more swiftly, resiliently, and decisively.

DoD Interests

The importance of operational energy needs for the US Department of Defense cannot be understated. The global geopolitics of the 21st century have shown that energy is a vital pillar not only towards military operations, but national strength and prestige. According to General David Petraeus's forward-thinking memo to US forces in Afghanistan, he stated that operational energy "is the lifeblood of our warfighting capabilities and a key enabler…"[2] Petraeus's message was clear. Not only was the military duty-bound to increase its performance within the energy domain of supplying its forces but also by raising overall efficiency and diversifying energy sources and distribution. If applied in a broader context from this 2011 memo, these principles of diversification, energy sustainability, and resilience can be applied to the entire DoD as emerging threats creep in on US national security interests from multiple vectors of attack.

It would be prudent, in this case, to see the need for a revamping of the DoD's approach to operational energy and recognize that the 21st century, while having more potential threats and means to carry them out against the United States, also has the technological means to combat these threats vis-à-vis advanced energy. As Italian general and air warfare visionary [Giulio Douhet] stated during the cradle of airpower, "Victory smiles upon those who anticipate the change in the character of war, not upon those who wait to adapt themselves after the changes occur." To secure American national security against an array of threats in the near-future, change must begin now in the pursuit of ways to create a more agile and resilient fighting force posture.

According to the Office of the Assistant Secretary of Defense for Sustainment, operational energy is defined as "The energy required for training, moving, and sustaining military forces and weapons platforms for military operations."[2] Effectively, operational energy is the means in which warfare can be carried out as it encompasses the energy required to sustain aircraft, naval and space assets, ground vehicles, permanent and contingency bases, forward operating posts, and even individual troop equipment. It is known that on average during the post-9/11 military, 75-80% of US government energy use is allocated to the DoD, with bases and installations alone accounting towards 30% of DoD's consumption.[3] Aircraft fuel furthermore accounts for 75% of all Air Force energy consumption, which is 71% of all operational energy needs; aircraft fuel is the largest fuel consumer category within the DoD.[4]

With the massive levels of energy consumed by the world's largest military, only about 9% of installation energy use comes from renewable or advanced energy sources.[1,5,6] Although the Pentagon has promised to increase this to 25% by 2025 in accordance with congressionally mandated clean energy requirements as outlined in EISA Section 33, progress has been limited.[7] Therefore, it is in DoD interest to pursue meaningful actions to meet this goal of greater advanced energy use, given the effects it can have on the military at-large.

Simply put, the DoD can reap the rewards of a better equipped fighting force for the 21st century. Pursuing advanced energy implementation and integrating it into the current force structure will involve overhauling operational energy sources and supply chains. However, the outcome of this will lead to the following benefits:

- Promotion of energy independence
- Reduction of logistical weak points
- Preparation for conflict with China and Russia in INDOPACOM and EUCOM
- Extension of operational reach through greater sustainment capabilities
- Increase of force resilience
- Increase of tactical adaptability

The current DoD force support structure, though having the sturdiest logistical system of any military on Earth, is still susceptible to inefficiencies, which can become larger problems if the United States has to contend in multiple theaters against near-peer competitors with capable weaponry. For example, over 70% of the tonnage used to position the Army onto the battlefield is hydrocarbon fuel.[4] Some 85% of the Air Force's fuel budget is used by airborne tankers to deliver 6% of annual jet fuel usage.[4] Furthermore, to display just how bulky and outdated such a system is relying on hydrocarbon energy across the spectrum of force readiness, over 50% of fuel sent in-theater is used by support vehicles delivering the fuel amongst other supplies, not front-line units. In fact, the cost associated with this supply chain is many times more than the fuel itself, driving up the costs of conflict. It is estimated that some 15 gallons per day is used per soldier on the battlefield, according to a 2007 study on the Iraq/Afghanistan conflicts.[4]

With such enormous inefficiency hindering a more streamlined cost to war, this can be self-damaging, especially when a scenario for conflict arises in multiple theaters simultaneously, spreading US forces thin. And though much of the energy the military requires is dedicated towards jet fuel and other platforms, which require energy density too high for current advanced energy technologies, the difference can be made "in the gap," or in other words, everywhere else, such as the 25% of the fuel needs of the Air Force outside of sustaining its aircraft. This would include more than half the needs of the Army, Navy, Marines, and Space force.[4, 5, 6] The shift to advanced energy would make a large difference: it would be a force-multiplier on the battlefield.

Operational Threats with Case Studies

Given the DoD's need and interest established above, it is necessary to also place emphasis on the operational threats that exist today, which can impact the current DoD energy infrastructure. Such operational threats can also be highlighted through case studies. Following are three key threat areas, each with their own salient examples.

First, land-based or sea-based hydrocarbon supply chains in Europe and the Pacific present a weak point that can be exploited by adversaries. As described earlier, the logistical supply chain transporting fuel and energy to sustain the operational energy demands of US forces is bulky and vulnerable. The Russian invasion of Ukraine in 2022 displayed the logistical ineptitudes of the Russian military infrastructure, and specifically, the vulnerability of fuel resupply. Columns of Russian armor and vehicles found themselves stuck on major roads without fuel, such as the 40-mile long convoy stuck for days without fuel north of Kyiv.

This highlights Gen. Petraeus's statement and analysis of the connection between energy and combat power. Ukrainian light troops managed to ambush multiple resupply convoys, targeting trucks specifically. Without these trucks, Russian tanks would not pose a threat and instead be stuck in the mud. A parallel can be made here to American forces in the Iraq and Afghan wars. Some estimates show roughly 1 in 8 American convoys were hit either by IEDs or light ambush from insurgents. Most of the cargo of these convoys was fuel, as much as 80%, and during the Iraqi “surge” between 2007-2010, hundreds of casualties resulted from these attacks.[2] Moreover, forces had to be diverted from offensive operations to defend convoys.

In the Pacific, Chinese capabilities have increased over the past decade to a frightening degree. Chinese long-range missiles are allegedly capable of taking out US ships, both combat and supply ships. Furthermore, fuel depots are also at risk. In an invasion of Taiwan scenario, US airpower and naval power will be challenged not only from the combat environment itself, but in sustaining their forces with operational energy. Bases from Okinawa to Guam can be potentially cut off from fuel resources.

The second significant operational threat is that of the geopolitical ramifications of an over-reliance on non-diversified energy. Diversity in energy sources is a great strength and way to neutralize weak points in American national security. Petrol states and nations that rely on their status as oil exporters derive influence and power from their ability to hold other states hostage. One only needs to observe the impact of the OPEC oil embargo, which wreaked havoc on the US economy in the 1970s contributing towards “stagflation.”

Currently, US diplomatic relations with Saudi Arabia are dictated by their wealth of energy. Russia, has notoriously exerted its will on Europe by being its largest oil and natural gas supplier, as evidenced by the controversy over the Nordstream II pipeline to Germany.[1,8] Russia is the third largest energy producer in the world, with 70% of its exports being accounted in the energy sector.[1,8] A global transition towards advanced energy, as is already underway in limited fashion, will be detrimental towards these petrol states’ power. European adoption of new energy sources and systems will directly lead to lower oil demand and imported fossil fuels, which will free it of Russian fossil fuel dependence.[1,8] Russia losing substantial revenue from this will directly impact its ability to sustain a large modern military and hamper its capabilities.

Finally, the third main operational threat is the collateral and cyber-attack potential on US military infrastructure and facilities, particularly attacks that disable an installation’s ability to operate without energy. There is tactical risk associated with bases in austere and deployed environments, where if no fuel is delivered, these locations become exposed and vulnerable. On an operational level then, significant risk arises in achieving timely objectives as a result of infrastructure attacks. Even on a strategic level, a fossil fuel dependent military will become less combat effective in the medium term. The scale of this problem is evident in that $8.2 billion in one year (FY 2017) was spent to provide 85 million barrels of hydrocarbon fuel towards operational energy to sustain 500 domestic and 750 foreign bases and location assets.[6] Furthermore, it is not unfathomable that a cyber-attack by a capable entity could cause severe harm to a large-scale electric grid. In the event of such an attack, US military infrastructure, at home and abroad, would be impacted—standard backup diesel generators can only operate for so long.

In the 2018 National Defense Strategy, the overall threat from a multipolar world with an array of threat vectors, as well as a highly visible challenge from near-peer competitors Russia and China, have made the need for a highly modern combat force apparent. The United States is emerging from a state of "strategic atrophy," as the conflicts of the future will not see US troops enjoying total air superiority or being able to operate logistical supply lines without disruption.[9] The game has changed.

Batteries

To address the national security concerns raised above, the DoD and US policymakers have the military and economic means to elevate US military performance in the area of advanced or alternative energy, which will be examined in further detail later. Now, however, the way in which this can be accomplished in a most efficient manner is two-fold, under the umbrella of key technologies. These key technologies are batteries and micro grids. Guided research and development, cooperative engagement between various institutions and agencies, implementation across the military's branches, and seamless integration into combat and support forces are all required to translate these technologies into viable solutions for the energy security needs of the DoD and US population as a whole.

Batteries: Simple in Their Basic Concept

Essentially, as energy storage devices, they store chemical energy before converting it to electrical energy, which powers our multitude of systems. Electrons flow from a cathode electrode to an anode through an electrolyte, and during this process, chemical reactions remove electrons. The resulting ions travel through the electrolyte, and the electrons travel across an external circuit which generates a voltage potential and thus, electricity. Recharging a battery simply redirects the flow of electrons back towards the cathode so that the discharge process can be repeated. This process is straightforward; however, the key in battery innovation is developing batteries that can operate in an array of conditions, as efficiently, and as economically, as possible. Military grade batteries require certain capabilities that demand better performance overall. Though developing this technology further would induce upfront costs, it would be fiscally and strategically responsible in the longer term.

Battery power has been increasing in an exponential manner over the last thirty years. With demand soaring in the commercial market due to more production of electric vehicles, Tesla being a prime example, and renewable energy systems such as photovoltaic and wind power, the United States must ensure it does not fall behind in this "green energy" race. The manufacturing capacity in Gigawatt-hours per year has rapidly increased between 2017 and 2020 alone in East Asia (notably in China, Japan, and South Korea).[10] Furthermore, the ability for batteries to compete against fossil fuel energy demand is also increasing. The cost of lithium-ion battery power is on the decline worldwide from $1000/kWh in 2008 to $200/kWh in 2022.[10] At the same time, the energy density of batteries, long considered a limiting factor of their utility, has increased from an average of 100 Watt-hours per liter to 400 by 2022, according to the US Department of Energy.

The two main challenges to large-scale fiscal shift towards battery innovation by the DoD instead of remaining in the status quo are on the micro and macro scales. On the microscale, much research has been dedicated towards improving battery discharge and charge rates, increasing the number of cycles or lifespan, and using materials and new reactions sustainable under austere environments. This is of great interest to the DoD due to the implications of such research. In the Russo-Ukrainian war of 2022, much of the Russian military's shortcomings are attributable to its materiel maintenance and acquisition. Evidently, Russian contractors and acquisition personnel chose to outfit vehicles with batteries of short service lives leading to no power in many vehicles that were subsequently rendered inoperable and abandoned.[11] It is therefore important to pursue military-grade batteries of higher quality since battery costs will continue to decrease in the coming years.

Currently, research in academia and industry is working on these microscale technical issues. For example, The National Renewable Energy Laboratory is looking into maintaining high capacity in batteries for storage by including a metallic lithium reservoir that can discharge into a cathodic electrode to combat the loss of cycle-able lithium.[12] Beyond this research into traditional lithium and novel silicon-based batteries, solid-state batteries along with phosphoric, silver oxide, and zinc-based batteries are consistently being developed, with funding being one of the bigger limitations and barriers. Other research is at work to ensure functionality and thermal stability at a wide range of temperatures.

The macroscale issues associated with wide-scale battery implementation tie into upfront costs associated with transitioning and maintaining material supply chains. However, research has shown promising signs. Given that permanent facilities such as buildings consume 50% of global electricity demand, the DoD can benefit by prioritizing its bases and installations.[13] Much of the cost issues involved in scaling up battery technology are better investigated in tandem with solar photovoltaic energy capture and other thermal systems integrated into a micro-grid, where solar and storage capabilities offer appreciable advantages to traditional diesel.[14] This larger scale advanced energy technology system shall be explored next.

Simply put, battery storage as a source of renewable energy is a highly viable option for major DoD investment. Unlike the recent $400/gallon costs associated with transporting diesel to front line troops, on-site battery capabilities and significant investment into their widespread implementation across numerous platforms and installations can see a 28-58% cost reduction by 2030.[15] Higher battery efficiency and lower costs achieved through R&D investment contribute towards a more viable and widespread model for alternative energy proliferation in DoD use. Although there are technical challenges to improving battery functionality, the solution is one of applied effort into pre-existing avenues (the means the United States and DoD have to enable change).

Micro Grids

Micro-grid systems provide a suitable way to provide advanced energy power while addressing both cost and resilience. As already described, various DoD bases and installations consume much of the energy used by the DoD. Therefore, it is prudent to consider adopting micro-grid systems across the board for US military needs.

Micro grids are essentially localized grids, which are able to be disconnected from the larger grid and operate autonomously.[16,17,18] Another term for this functionality is commonly known as "islanding." In this manner, micro grids provide an unmatched level of grid resiliency, and they are able to combat disturbances, whether natural disasters in austere locations or attacks, to the benefit of DoD.

Since traditional grids operate on the principle of interconnectedness, issues with one portion of the grid affect another. Micro grids localize damage or disruptions. This kind of damage mitigation is vital for successful military operations. Although micro grids are designed to enact islanding protocols during crisis moments, properly sustained models with renewable energy supply and storage capability can allow long-term self-reliance. The cost aspect is evident in the use of distributed energy sources such as photovoltaic (PV) or solar power, fuel cells (FC), and wind power—all integrated with battery storage and discharge capabilities delivered to desired loads via direct (DC) current. Because these energy sources are localized to the required area, they are known as distributed energy resources, and without the inherent dissipation and energy loss associated with transmission, micro grids provide lower cost power at a more efficient rate in many situations.[16,17,18]

Cost and resiliency are the major measurements of micro-grid success over traditional systems. From these attributes, DoD capability can be extrapolated to be more efficient, effective, and adaptive in hostile situations. In aggregate, the DoD can potentially save up to $1 billion across the DoD per year.[19] A single larger size base can save $8-$20 million over a twenty-year lifespan.[19] This kind of margin would offset any short-term costs. A recent case study of a Californian telecommunications facility has yielded promising data to support this.[20]

A micro-grid system that can disconnect from a main grid through "islanding" and which is a hybrid, that is, solar and storage with diesel, has 1.8 net days of resiliency on average more than installations depending just on diesel, once an electrical grid failure has occurred. Some of the higher estimates put the resiliency gain to six days of fully independent energy generation, using a hybrid system. Although only $104,000 cost savings were associated with the micro grid in this project compared to the $519,000 savings of a grid connected system, micro grids allowed for a 91% utility energy savings margin.

Further studies have shown promising results in large scale implementation of micro-grid systems. A detailed study by the Los Alamos National Laboratory has found that DC micro grids are highly efficient and low-cost platforms for mass implementation.[21]

Specifically, distributed energy in the form of PV + FC + Battery DC micro grids, maintains an advantage over other electrical systems in certain circumstances at about $1/W lower with appropriately sized energy assets. However, a 2-3% efficiency increase in a DC micro grid is observed compared to traditional AC grid structure given the assumption that energy is not exported out of the island. Moreover, engineering costs are also advantageous given universal control systems and switches.

A further examination of micro-grid superiority reveals that traditional diesel generators are archaic in the modern day. Many generators are idle, unmaintained, and susceptible to failure, as has been the case in the Caribbean during hurricane events.[14] In various models, micro grids show an ability to be adapted towards different loads and needs. For example, a model built around a large school showed total bill savings through reduced demand cost and energy expenses offset lifetime cost of the system as well as upfront installation. The effect of resilience was a 13x increase in energy storage capacity of the system.[14] With all the above parameters, the survivability of the micro grid, allowing for steady-state operations with little loss of critical load or voltage drops during a disturbance, points to an exciting opportunity for the DoD to adopt this technology system across its force structure.

To summarize, the game-changing nature of micro grid systems, the dual effect of distributed energy sources paired with battery storage, can be used to effectively manage mission essential loads and energy demands in the event of a disturbance whereby the grid will switch to islanding and be able to sustain supply and demand needs.

Instruments of Power

The United States has the ways to address national security vulnerabilities associated with energy through two key technology solutions: battery power and micro-grid systems. The good news is that the United States and DoD possesses the means to implement those solutions in a timely manner. These means exist in two main domains: the military and economic instruments of power.

Thankfully, the DoD has recently been made aware of its need for new and vigorous developments in alternative energy technology, particularly operational energy. The Office of the Assistant Secretary of Defense for Sustainment (OSASD) was formed only recently, in 2018, as part of a restructuring and reorganizing of logistics and materiel commands for the DoD. This was in part a direct response to the 2018 National Defense Strategy, showing that adversarial capabilities were increasing, opening vectors of threats upon the homeland. According to 10 USC §2926 of the US Legal Code addressing operational energy concerns, the Assistant Secretary of Defense for Energy, Installations and Environment shall "oversee the operational energy activities of the Department of Defense, including the activities of the working group established under subsection (d), and oversee the investments of the Department in such activities."[22] Thus, a legal chain of accountability has been created with a clear organization and mission. Much too often, policies of research and development (R&D) and modernization become muddled without clear guidance, proper responsibility, and lack of accountability. However, a clear line of effort and chain of command established in recent years has allowed for better oversight by the DoD over projects related to improving energy security.

In fact, many steps are already being taken to pursue the interests of advanced energy methods.[29] A change in philosophy has been adoption of *resilience* as a guiding principle. According to a 2013 memo by the Acting Deputy Under Secretary of Defense for Installations and Environment, before energy was officially included, "Climate change increases the likelihood of such events [Hurricane Sandy], and the DOD must be prepared for and must have the ability to recover from utility disruptions…. The necessary planning and capability to ensure we have available, reliable, and quality power to continually accomplish DoD missions from our installations in the face of such disruptions can be described as power resilience."[23]

In this respect, battery and micro-grid innovation represent the best and most attainable avenues of innovation and integration. There is already historical precedent in place, modeling the various lines of effort the DoD can take. For example, a 16.4 MW photovoltaic array went operational at Davis-Monthan AFB (AZ) in February of 2014, showing a genuine consensus amongst Defense leadership that energy was a vital concern and worth spending on novel conservation efforts.

At least $1.6 billion has been invested into energy RDT&E since 2019.[1] These funds are allocated to small troop units, permanent and contingency bases, vehicles, autonomous systems, and battery systems, which alone received $430 million in the 2009-2012 timeframe.[6,24,25] However, with respect to battery and micro-grid initiatives, the DoD has also begun funding and pursuing these technologies. The DoD sponsors a wide range of organizations and projects within the private sector, in academia, and in industry, towards technology acquisition and sustainment. It is an iterative process to develop innovative technological solutions, and therefore, a high degree of end-user to design mutual connection must be maintained through better streamlined processes.

According to the Fiscal Year 2020 Operational Energy Budget Certification Report by the ODASD, streamlined processes have emerged for renewable energy acquisition towards operational energy need.[24] A new basic framework of "Branch, Program title, Initiative title, Project description, Strategy Objectives, and Budget" allows for simple uniformity across all the service branches amongst the defense acquisitions community. For example, the following projects are currently in the 2022 budget:

- Beyond Lithium-ion Energy Storage 16 ($4.5 million enhancing warfighter capability)

- High Voltage Modular Lithium-ion Battery 17 ($6.8 million enhancing warfighter capability)
- Energy Efficient Devices Technology 84 ($27.5 million enhancing mission effectiveness)
- Battery Development and Safety Enterprise ($6 million enhancing storage power controls and distribution).[25]

Other government initiatives include the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs overseen by the National Science Foundation. Often described as America's seed funds, they support small business applicants seeking to develop innovative technology. The funds allow startup technology companies to become established and pursue their projects without the strain of early financial debt. Pairing the private sector and commercial businesses with accountability towards the DoD, which provides funding, is a highly effective way of inducing rapid and impactful change.[18]

The 21st century paradigm of technology procurement has flipped. In previous eras, impactful innovations such as GPS and computing started out in DoD research labs and were eventually ported over to commercial applications. This is no longer the case, as defense acquisition personnel increasingly seek out commercial innovation, which often leads to lengthier acquisitions cycles. Having streamlined systems with consistent technology readiness level reports, iterative communication between businesses and government, and dedicated personnel to manage these relationships all mitigate friction in this process. The DoD can afford to pursue early adoption and procurement of products from startups that do not yet have viable consumer market demand, functioning as a pilot customer. The vast resources of the DoD enable it to handle more risk of early development failure and endure higher starting costs, problems that typically kill early technology companies in the regular market. This DoD-business partnership also provides feedback for wary investors to step up and propagate what amounts to a new technology sector of the economy, bolstering other lines of effort towards the procurement and broad application of, in this case, battery and micro-grid innovations.

More specific initiatives include the Battery Network Manufacturing R&D Program as well as the Battery Innovation Center, the latter enabling effective means of quick battery capability testing with a designated facility. In the vector of micro-grid implementation, more than twenty pilot projects have been started at various installations under the Smart Power Infrastructure Demonstration for Energy Reliability and Security program (SPIDERS).[26,27] These projects include Fort Carson, Camp Pendleton, Maxwell AFB, and other projects across all branches. These projects are examples of test beds, where systems can be tested and validated at differing conditions.

The Environmental Security Technology Certification Program (ETSCP) has implemented the Installation Energy Test Bed, funding thirty-two projects on DoD installations for demonstrative and proof of concept purposes.[18] These micro grids also implement a test for novel battery storage systems with more capacity and longer lifecycles. As an example of the success of this program, Marine Corps Air Ground Combat Center Twentynine Palms employs a micro grid capable of operating 10 MW off-peak and 26 MW during the summer.[18] The Marine Corps Air Station Miramar in San Diego has a similarly scaled system, costing $20 million and integrated with diesel generators yet capable of sustaining operations if they are out of service. All in all, these examples showcase advanced battery technology integration by ensuring rapid response to various load demands thanks to efficient discharge cycles.

Other developments allow for the use of small-scale tactical micro grids in austere contingency bases, requiring portable components and fully self-sustaining systems. In this case, PV+battery+fuel cell integration is most useful. Such technology allows for small-scale rapid response forces in combat zones to be fully self-reliable in their operational energy needs. In fact, the Army is already exploring this model using the newly developed Advanced Medium Mobile Power Source (AMPPS) micro grid.[28]

Overall, the United States enjoys a strong and thriving technology sector which can spearhead development. However, government to private sector partnerships should seek to connect laboratory innovation to commercial application and required defense user needs and design constraints. Furthermore, multi-round competitive contracts and long-horizon oriented investments must be used in increasingly streamlined acquisitions processes with regular technology readiness level updates to the customer (DoD) as well as R&D "check-ins" from investors.

Policy Proposal

1. Promote public-private sector investment arrangements to connect laboratory innovation to commercial application (DoD customer).

2. Increase DoD budget towards ODASD(OE) from $1.6 billion for larger investment opportunities and subsidizing of industry and academia partners to cover the full spectrum of operational energy needs in a plausible near-future environment (25% of total OE needs).

3. Increase significant cooperation between DoD, DoE, research universities, and private businesses through multi-round competitive and long-horizon investments with technology readiness level updates and R&D milestone checks.

4. Implement incremental infrastructure and logistical restructuring to allow for

implementation of both permanent and tactical micro grids in tandem with novel batteries across an array of platforms and systems.

5. Scale back use of archaic logistical supply networks based on fossil fuel resources for OE needs.

End State: A more energy resilient, efficient, independent, self-sufficient, adaptable, and capable (tactically, operationally, and strategically) force structure across all branches of the Department of Defense, primed to sustain critical missions in a 21st-century combat environment.

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