2021-07-12

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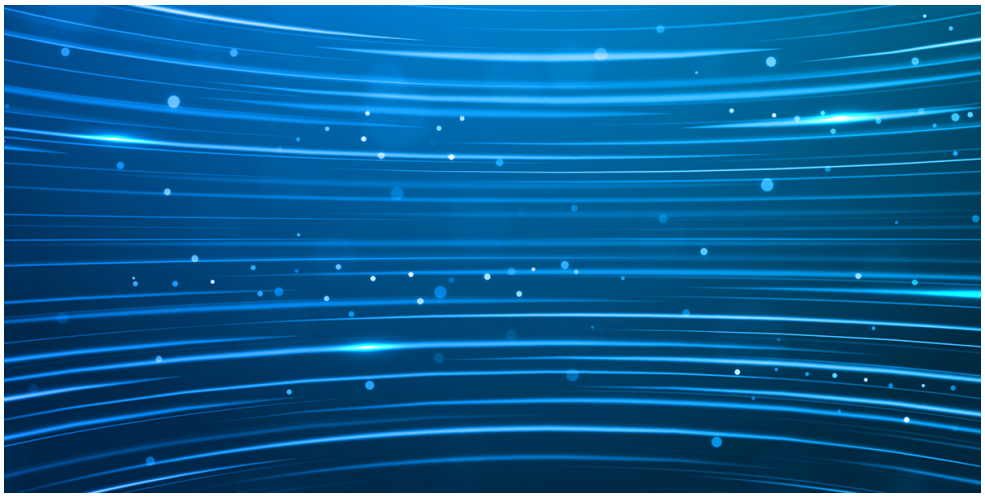

Operational Energy—Essential Knowledge for Military Officers

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The Department of Defense defines operational energy as "the energy required for training, moving, and sustaining military forces and weapons platforms for military operations."[1]

Operational energy (OE) can be thought of as a foundation of national defense and an *indispensable* attribute of military strength. It is essential for almost all forms of combat, and "commanding it" properly will be even more critical in the future. Over the past 100 years, energy has evolved to power literally every military capability of consequence. For example, OE 1) powers almost all forms of communication and sensing; 2) fuels all air, land, sea and space platforms; 3) energizes all electrical devices; and 4) is becoming a primary direct-fire weapon. Often considered a "vital national interest," the access to energy itself is often a *casus belli*—a reason to go to war. Moreover, since the beginning of World War I, operational energy (OE) has played a decisive role in all major conflicts. This paper emphasizes 1) why officers should be educated on OE, 2) what officers must know about OE, and 3) when officers need to be educated as they progress through their careers.

Why Officers Must Be Educated on Operational Energy

OE is an integral aspect of both the direct and indirect methods of warfare, and it is laced throughout all spectrums of conflict. While it is true that since World War I the U.S. has enjoyed energy superiority, it is also true that the world is evolving, and U.S. OE

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predominance is being challenged by nations like China. Based on historical conventional warfare, the victor dominates energy capability. Therefore, OE is a technical capability in which the U.S. must lead. Victory in the OE domain occurs when 1) there is efficient, effective, and sustained production of combat power when and where it is required by friendly forces, while 2) the enemy combat power production is disrupted, degraded or destroyed. OE superiority is the ability to fully exploit one's own energy capabilities while preventing the adversary from doing the same. These should be the primary U.S. goals and ones America must attain. The military officers for all Services are focal points for realizing these goals.

Today, the Secretary of Defense's Operational Energy Innovation office focuses on three primary areas of OE development: 1) powering the force, 2) electrifying the battlespace, and 3) commanding energy. Powering the force is generating and maneuvering energy to all fixed and mobile platforms while reducing vulnerability. Electrifying the battlespace is evolving OE into more efficient, effective, and less vulnerable electrical power that can accommodate multiple power sources. Commanding energy is near real time energy awareness, command, control, and education at all levels. No longer can the operations commander simply trust the logisticians to have fuel in place. In the future, OE decisions will be more complex and will require an immediate understanding of the battlespace before maneuvering and expending OE.

Nations are rapidly developing and beginning to field directed energy weapons, railguns, lasers, particle beams, and microwave arms. Within a few years, these weapons will dominate the battlespace. Future force concepts envision highly dispersed forces throughout large geographic regions that require immediately available OE. Without an abundance of ready, secure, and forward-based OE, future militaries will falter and fail. *Therefore, it is paramount that the Department of Defense comprehensively educate officers on OE throughout their careers. It is important that military leaders understand OE needs and capabilities at tactical, operational, and strategic levels of conflict. Officers should also realize how OE in all of its forms, within multi-domain warfare, is positioned, maneuvered, and exploited within any given battlespace.* Officers must know how to integrate OE planning and execution at all levels of war, maintaining a near real time OE understanding and command throughout all aspects of the battlespace. Officers must also understand resourcing and developing more advanced energy capabilities.

Modern OE is much more than positioning fuel and ammunition. While it includes those elements, warfighting OE is about managing multiple types of energy sources (e.g., petroleum, solar, hydrogen, nuclear fuel); generation (generators, convertors, reactors, etc.); distribution (e.g., electrical wires, power beaming); and storage (batteries, convertors, storage tanks, etc.). Warfighting OE addresses all forms of power to include soldier carried batteries, weapons (e.g., energy weapons, battery powered missiles/bombs, etc.); weapon platforms (e.g., tanks, planes, ships, satellites, etc.); forward based microgrids; and cyber/communication systems through all warfighting domains that are required to accomplish military missions. Command and control of warfighting OE is about understanding the energy status across the battlespace and directing adjustments, sometimes very quickly.

Military officers must understand current OE and the future battlespace as energy technology evolves. OE powers both physical and virtual realms. In future warfare, strategic OE will be optimized and directed by guidance from the National Defense Strategy. OE

must be capable of enabling deployed platforms and weapon systems that are dispersed from home basing to forward and operating locations that are vulnerable to enemy attack. Many of the future weapon systems will evolve from petroleum motors to hybrids, and then to fully electrical/alternate fuel engines that are charged from wireless support systems.

Energy education in DoD should be across all levels and for the long term. As with industry, such education should be connected with universities, think tanks, and the private sector. DoD is learning from outside of DoD and currently working with numerous universities and civilian labs. This is key to ensure efficiencies and synergies happen in positively dynamic ways.

What Officers Must Know About Operational Energy

There is no doubt that the DoD budget will be under stress in the coming years. A significant part of the Department of Defense (DoD) budget is for energy (sources include DASD (Energy) documents and Wikipedia (Energy Use of the U.S. military for)—$9.8 billion and surging to $14 billion during recent conflict. DoD is the largest single consumer of energy in the world, and within DoD the largest energy consumer is the Air Force. About 85 percent of the fuel used in DoD is for OE applications. In regard to combat, one in eight casualties in the Afghan and Iraq Wars happened during fuel movements. Therefore, a focus on OE education and training will have a major impact on OE development, budget, and operations, saving lives and helping to ensure mission success. If officers of all ranks are trained in energy, much improvement can be accomplished. If officers understand how OE systems operate, missions might be accomplished with less energy or with alternate sources.

DoD must provide officers the basics, give them incentives to continue to learn and improve energy employment, and use energy at the tactical, operational, and strategic levels. Furthermore, there are spillover developments from DoD into the civilian sectors, and energy interchange from the civilian sectors into the DoD as well. As a matter of total investment and economies of scale, the civilian industry energy sector dwarfs DoD. Therefore, joint military/industry OE development and investment is necessary for DoD to realize the best economies of scale.

What should our officers and others know about? Clearly, they need to learn about the past, present and future potential energy resources used in operational energy as foundational knowledge. This includes crude oil, various refined products, liquid natural gas (LNG), dry natural gas, and electricity generation in its many forms and processes. History is a wonderful educator and can help provide insight to the future. In conventional wars over the past century, OE has played a pivotal role in regard to combat success and failure. Officers need to understand the technologies, supply chains and how to think about present and future energy supplies and uses, and how it all impacts combat operations.

A clearly important step toward improved energy education for officers is the development of energy doctrine that reflects the current energy environment. The Services use doctrine to establish baselines for education, training, and operations. Today, comprehensive energy doctrine does not exist. The energy doctrine that does exist is focused on liquid fossil fuels.

Military officers and both S&T and A&S civilians should study the energy ontology because it provides a framework for understanding energy issues.:

- Sources—the basic element the “contains” energy (petroleum, coal, sunlight, etc.)
- Power Generation/Conversion—converting sources to useable energy
- Transmission/Distribution—making energy available to users
- Storage—storing energy for later use (challenging for electricity)
- Energy Management—awareness, command and control of energy
- Tools & Analytics—improvement of current systems and developing new capabilities
- Platforms—mobile vehicles of all domains
- Weapons (military only)—includes energy weapons
- Education & Training—continued instruction

This ontology provides a foundation for comprehensively understanding the energy process and chain.

It is important for officers to understand that electricity is converted from multiple energy sources and is also a source of energy itself. There are many ways to generate electricity, such as solar photovoltaics, concentrated solar power, spaced-based solar, wind power, tidal and wave power, biomass, geothermal in its various forms and methods, as well as coal, natural gas, oil (rarely in the U.S., but many countries rely a lot on oil), and nuclear power.

Nuclear power is mostly fission now, but fusion energy has distinct future possibilities. Small modular reactors (SMRs) have considerable potential for operational energy with the proper safeguards. An example of nuclear advancement is the TRi-structural ISOtropic (TRISO) particle fuel. It has real potential, especially for smaller and/or mobile reactors. TRISO particles are composed of uranium, carbon, and oxygen. In turn, this particle is encapsulated by carbon/ceramic type materials which hinder the release of radioactive fission products. Because of the coatings, each particle is its own containment system and cannot melt in a reactor. This is a type of development that military officers must remain educated about. This technology has the potential to radically alter electrical generation by nuclear means.

Officers and others also need to understand the proliferation, safety, and command and control aspects of various nuclear power systems, including, but not limited to platform and FOB energy systems, but also as sources of energy storage and energy storage improvements.

DoD personnel need to know how the many energy systems work to run operations with full knowledge, and to know what to do when systems fail, including chain interruptions. Some of the most important things to understand in energy for leadership, logisticians, and others are the entire supply chains for each type of energy and the risks along those supply chains. Understanding the risks are especially important for a number of reasons. These reasons include knowing the costs and benefits for energy development and the operational challenges that might exist without proper investment.

As part of the supply chain, understanding some understanding of both large and small electricity grids as well as microgrids and battery and storage systems needs to be taught. This is not to get DoD personnel to be experts on electricity generation, storage, transmission, and distribution, but to ensure they understand how these systems function. This may also help in understanding how to restore essential electrical systems in times of conflict and war.

Such supply chain understandings could also include refineries, LNG facilities, energy port facilities, energy shipping and other transport, and how energy is used in shipping and transport. Officers should understand how the full oil and natural gas supply chains work to understand the weak and strong points of the supplies of these important sources of energy. Energy is target and can be vulnerable if not operationalized properly. This knowledge and understanding of supply chains could also apply to energy storage.

Energy storage can come in the form of batteries, pumped hydro, flywheels, chemical reaction, or heat storage (e.g., molten salts). Energy storage systems are not just for routine storage, but can be backup as a vital and life-saving source of energy in times of stress when all other sources are not working. Energy storage can also tide over an FOB when deliveries of fuels or other methods of producing needed energy are not available. Having more on-site energy production at FOBs is also a way to improve their energy security. Shaping availability and efficiency in the use of energy and less energy waste is the role of a commander.

A potentially massive source of energy that many do not consider is energy waste. Overall, the U.S. wastes about 68 percent of the fuel we put into our energy systems. The biggest sources of wasted energy are in electricity production and transportation. DoD electricity production and transportation are some of the most important uses of energy. Much can be done to use waste energy more efficiently. Exploited waste energy is energy that does not have to be transported into the battlespace, reducing risk and possibly casualties. Such an effort could end up improving budget stress and saving lives.

Consider the FOB that only needs to resupply its fuels every three weeks instead of every week. Think of the Navy ship that can go much further on a tank of fuel and not need to be resupplied multiple times while crossing the Pacific. Consider the nightmare scenario of numerous flying and floating fuel tankers being destroyed or put out of action and one can see very clearly why better energy use can save lives and missions.

Almost all our ships, vehicles and aircraft are fueled by oil-based products. Along with the risks associated with not having onboard energy generation are the risks associated with the volatility of petroleum and refined products prices. Understanding energy markets at the squadron, battalion and even troop levels could be life and mission savers at times. Transportation energy markets are vital for officers, and especially logistics and planning officers, to understand. These are also crucial for intelligence officers.

Understanding energy markets will not only enable them to estimate their budgets and needs, but this will allow them to understand the risks involved with relying on specific markets for energy, energy storage, and more. Diversity can be key to saving lives and mission success. Understanding markets—and subsequently bettering knowing energy economics—also means they will better understand possible new technologies, new entrants into the markets, the competitive or contestable nature of the markets, energy substitutes and complements, and how energy markets may be interlinked. Much of our solar, wind, and other renewable technologies are imported. It is important to understand how tariffs, quotas, trade disputes, and trade agreements may affect the ability to get those technologies affordably, reliably, sustainably and on time.

The supply chain for natural gas, coal, and renewable technologies and devices are directly linked with electricity markets and the auctions and other local and regional markets associated with them. The supply chains for natural gas and coal in the U.S. are mostly

domestic. The supply chains for oil and oil products have important international aspects that need to be considered. If the fuel is needed outside of CONUS, then a deep understanding of the local, regional, and global markets for fuels and technologies needed in the area is crucial. Currently, the Defense Logistics Agency addresses much of these issues for DoD. However, future senior leaders may be involved with this aspect of energy support.

It is also important, whether it is in CONUS or OCONUS, to understand the applicable regulations and laws for each form of energy to be purchased. Oil markets are mostly global markets, but there may be local, regional, and national rules that can apply at times. It is often the case the natural gas markets are regional, but the distribution of natural gas is often local with local rules and regulations. Electricity markets can be some of the most regulated of markets via public utility commissions or their equivalents. Then there are electricity markets that have been unbundled with the generation, transmission, and distribution being done by separate entities. It is not only important to understand who you need to communicate and negotiate with, but also how stable and controlled prices may be over time. Understanding local electricity auction markets also helps with hedging, whenever that is allowed. Each electricity market—CONUS and OCONUS—has its own peculiarities, but it is also important for an officer to understand what a market is and how markets can behave at times, including times of stress.

Transmission and distribution systems are different aspects for moving electricity. Electricity transmission means sending the electricity at very high voltage over transmission heavy pylons and similar structures. When this transmitted electricity is stepped down in voltage into a distribution system, then it could be an organization that establishes and maintains the system.
For natural gas, the transmission pipelines are usually high volume and over long distances. These pipelines then connect with the distribution pipelines to houses, hospitals, hotel, factories, and the like – as with electricity. Oil transmission pipelines (trunk lines) carry crude and refined products— like jet fuel, diesel, and gasoline—over long distances and often in the same pipelines at the same time. Then at various terminal points these products are distributed to various customers. Understanding and mapping out these systems are crucial for an understanding of points of failure, other risks, and the places that may need extra protection. Understanding and mapping out these systems could be the source of important intelligence for an operation.

An understanding of energy storage could be the difference between success and failure in an operation. Storage can take many forms, such as batteries, pumped storage locations, flywheels, and the like. Without proper energy storage, renewable and other energy systems could become unstable or even unworkable at times. Determining the optimum way for soldiers and others to carry batteries and recharge them could mean the difference between not only victory and defeat, but life and death. The importance of storage should start at the level of the sailor and soldier and go all the way up to battery systems in ships and large ground and air transport vehicles. Batteries and other storage are also important for personal and squadron communications all the way up to major battlefield ISR. Energy storage is important for cell phones and drones, for example. With an electricity grid down, an officer should know where the energy storage is coming form or where new supplies could be produced onsite or be transported in.

Platform energy is clearly something officers need to know about. If an officer does not clearly understand the energy that is powering the ship, the aircraft, and transport vehicles they are using, miscalculations at the tactical and even strategic levels can happen. These can result in mission failure in the near term and service and national failure in the longer runs and in the bigger pictures. Lives can be lost due to these miscalculations.

Energy weapons can pull heavily on the energy supplies of an operation. They can be connected directly to platform energy in some instance. On some platforms, such as energy-integrated ships, the energy used for weapons is from the same source as the power that runs the ship. An officer on that ship needs to understand the tradeoff between powering the ship, and moving forward in battle or an exercise, and firing the directed weapon. The energy used for powering energy weapons might be considered "bullets." When you get low on energy, you run out of bullets.
An officer should also understand the safety issues related to fuels, electricity, and nuclear power, when these apply. Officers need to train their personnel on these safety issues. One of the characteristics of high-voltage electricity systems is electric arc. Electricity can jump long distances. This can cause injury, death and can also damage a platform and other equipment. Proper grounding is just a small part of handling electricity. When an officer is dealing with the possibility of an electric arc, that represents a significant hazard. It also requires the implementation of appropriate controls at an FOB, an aircraft, and a ship.

All the above apply to wargames, training, and exercises. When preparing for a large, or even a small, operation, officers need to know their energy requirements, energy use, energy safety issues, available energy storage, and the energy supply chains to sustain the operation. Energy logistics supply chains are the backbone for any operation. Whether the supply chain is across a small island or across the globe, it is important to understand it. Energy must be an integral part of military command and control (C2)—either as an independent system or as part of a comprehensive C2 system.

There have been many operations in the past, and there will be operations in the future when "for the want of a nail" they failed. Napoleon and many others, such as Rommel, lost significant battles due to running out of fuel. For Napoleon it was horse feed. For Rommel it was fuel for his vehicles in the desert. One of the most important reasons to run pre-conflict war games is to find estimates of what material, personnel, and energy will be needed for an operation. If Napoleon and Rommel ran war energy games with knowledge of the real potential risks possibly the results would have been different. Of course, the reality of real combat and other operations often lead to surprises. An officer need not compound those risks by miscalculating energy needs at all levels from small battery packs to the refueling of platforms, such as ships and aircraft.

It is very important that an officer understands what energy support there is for operations and training for those operations. DLA-Energy is the major logistical support in DoD for its energy needs. DLA-Energy works with the private sector and others to ensure there is enough energy of many types for operations in battle and outside of battle. They are the major logistical arm for energy for the entire DoD and others. Officers need to know how DLA-Energy works and how to be part of and use the DLA-Energy system.

A visit with DLA-Energy should be a must for all officers who are involved in the logistics and planning of major operations. This is especially so for officers who are involved in command and control of operations. They or their staff need to be in touch with DLA-

Energy before, during, and after the operation. Without enough energy and energy storage, that command and control could lead to command failure, loss of control, and mission failure. And that could lead to higher casualties and other major costs of any operation both great and small.

Looking into the future, an officer of the twenty first century needs to not only understand the energy requirements of the force today, of his operations and training of today, but that officer needs to understand possible future force requirements for energy and its related physical and knowledge infrastructure. War and conflict have become more energy intensive and more energy-complicated over the years. Energy is a vital enabler of combat, ISR, and other operations.
The days when an officer only needs to count heads, platforms, and bullets never was, and never will be. All wargames and actual combat and other operations need to be done will full knowledge, including the risks, uncertainties, tradeoffs, and supply chains with their specific command and control aspects of the energy needed for such activities.

An adequately prepared officer will know what is needed to sustain readiness and all phases of operations. A strategic minded officer needs to think about and learn about where the energy requirements and uses of the future may be coming from. That officer needs to keep in touch with industry, universities, think tanks, national laboratories, DLA-Energy, and more to keep energy knowledge fit.

Indeed, given the importance of energy in operations, officers involved should have energy education as part of their fitness reports. These reports should also have markers for how well that officer plans, uses, and develops operational energy in his/her areas of responsibility. That includes more than keeping the diesel tanks topped off and the batteries in good supply. There is a new world of battle coming, which could be far more energy intensive. If a U.S. officer is not ready for this, mission failure could result.

The use and understanding of operational energy by our enemies and competitors is increasing rapidly in some cases, such as China. We need to ensure we will have an edge and are ahead. Having a corps of energy officers who are constantly testing the energy pulse of their area of responsibilities, and who are also looking to the future energy challenges near and far, will be required. There is no place for complacency in a quickly changing operational energy world.

When to Educate Officers on Operational Energy
As the Department addresses the importance of OE throughout our forces, we must employ a holistic approach to education and training. DoD must expose our officers to OE issues early in their career, update them often, and focus information relevant to an officer's rank and position. Then we can ensure that the everyday OE challenges our officer corps must consider are framed within the OE reality and complexity.

OE impacts warfighters every day in many ways—whether or not they realize it. Unless OE is considered and integrated into every decision, mission outcomes at the strategic, tactical, and operational levels may not only be suboptimal, but even risk failure. Therefore, DoD must first educate officers at a tactical introductory level. Then as officers progress through their career's specific responsibilities, more operationally focused aspects of OE must be taught. As officers are promoted and given greater responsibility, they must be taught about strategic OE as it impacts overarching planning and management of the forces.

Basic OE Education—Officer Training/Candidate School and the Service Academies

At the start of an officer's career, they should be taught OE concepts and basics, and the impact on current tactical operations. Basic officer training and the Service academies are excellent places to begin this effort. OE education might be accomplished as an overview course that 1) introduces officers to the multi-disciplinary considerations of energy, 2) shows how mastering these OE issues provides a strategic, operational, and tactical advantage over enemies, and 3) illustrates how failure to master OE presents an opportunity for enemy exploitation and friendly mission failure. Some key educational areas include:

- Understanding the basic energy ontology and how it functions
- Energy Superiority
- Knowing energy sources and generation for tactical platforms and weapon systems
- Exploiting and maneuvering energy
- Knowing Basic OE resourcing and logistics

Intermediate OE Education: Functional Career Courses and Intermediate Service Schools (ISS)

More tailored and detailed OE education should be integrated into the functional career courses (e.g., Supply Corps School) and ISS. Functional schools must teach special understandings of OE and the OE supply chain relevant to that area. A lack of OE understanding could create vulnerabilities in our forces for the enemy to exploit. In the Navy, engineering duty officers (EDOs and Civil Engineer Corps officers) must have tactical and operational understandings of the broader OE issues that impact mission performance. Many other specialty areas rely on OE and/or may be vulnerable to OE shortfalls. We must educate these officers on OE considerations as we prepare them for conflict. ISS is a tremendous opportunity for OE education. Most of these schools extend for a period of 10 months or longer and educate students in operational warfare and strategy. OE is a critical element in operational warfare and must be mastered.

- Knowing joint/coalition operational/theater OE planning and execution
- Understanding operational command and control systems and OE components
- Conducting wargaming and field exercising that includes OE
- Operationalizing advanced near to mid-term energy systems
- Knowing Adversary energy systems and interdicting them

Senior OE Education: Senior Service Academies

The senior leadership (flag and SES) complete leadership courses upon selection. In addition, the vast majority attend a senior Service school. During this education, these senior leaders should be introduced to the high-level, strategic considerations of OE and how these issues impact planning, operations, and management of the forces. We need our senior leaders to have a solid understanding of the strengths, weaknesses, opportunities, and threats presented by OE, not only to command operational forces, but to help advance military OE. Key energy areas that senior leaderships should focus on include:

- National OE leadership and development
- National energy resourcing and strategic stockpiles
- Future OE systems, economics, and funding
- Global energy command and control systems

Wargaming and Tabletop Exercises (TTX)

Integrating realistic OE considerations and challenges into wargames and TTXs is critical education for officers. The military fights as it trains. The frequent use of wargames and TTXs provide ideal opportunities to train in OE and reinforce the important impact of OE in military operations. In fact, if we do not integrate realistic OE into these wargames and TTXs and instead fairy-dust, gloss over, minimize, or entirely erase the risks presented by OE (such as minimizing logistical challenges, the potential loss of energy at FOBs or installations, etc.), this is not only unrealistic, but can actually degrade our officers' understanding of the dangerous consequences of a lack of OE awareness.

Major Military Exercises

Outside combat itself, the most effective OE learning can be gained through actual exercises. Military exercises can provide realistic combat training in any area that is orchestrated into the event. Energy must be a primary aspect of all military exercises whenever possible and appropriate.

Conclusion

OE is a physical force, powering microgrids and platforms as well as operating as a weapon itself. OE powers physical and virtual realms, and future warfare demands that energy be operationalized with its full capabilities employed from forward operating locations. Most of these future weapon systems will likely evolve from current engines to hybrids, and then to fully electrical engines that are charged from power beaming systems. These are some of the many reasons why officers must be educated about current energy capabilities and the development of future systems.

It is therefore important to educate our officers early, often, and in job and functionally relevant ways throughout their careers and at all levels of the officer corps if we are to effectively address the opportunities and threats presented by the ever-increasing importance of OE.

Sun Tzu noted, "In all fighting, the direct method may be used for joining battle, but indirect methods will be needed in order to secure victory. These two in combination give rise to "an endless series of maneuvers." Today, OE is an integral aspect of both the direct and indirect methods and is integral throughout all spectrums of conflict. Since the beginning of the 20th Century, the U.S. has had "energy superiority," but this is being challenged today. The U.S. must be first to lead in the OE domain. This should be a primary U.S. goal that America must attain and of which officer energy education is an essential aspect.

Notes:

1. Office of the Assistant Secretary of Defense for Sustainment website, https://www.acq.osd.mil/eie/OE/OE_index.html, accessed 22 January 2021

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