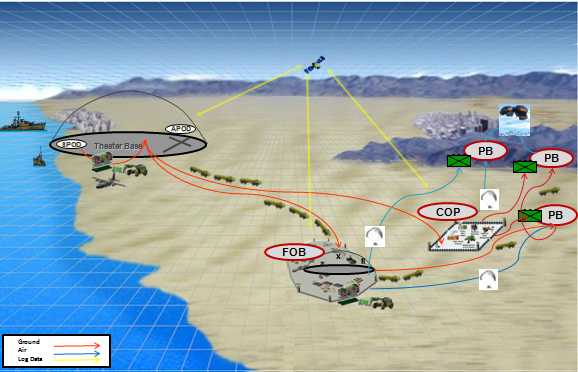
**Operational Energy**

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# Operational Energy (OE) is defined as the energy required to support, “military deployments, across the full spectrum of missions; direct support of military deployments; and training in support of unit readiness for military deployments.” This assessment of the system of systems has been scoped to focus specifically on the distribution system of the architecture. This is shown in Figure 1.



**Figure 1. OV-1 OE Distribution.**

Since OE is comprised of a broad number of systems, the assessment here can be expanded to include those other elements by utilizing the same logic and supporting requirements. The specific bounds of this project were ground and air transportation of supplies and personnel from the entrance into theatre at the Sea Port of Debarkation or the Air Port of Debarkation (S/APOD) to the bases and from bases forward, including all aspects of planning, tracking, protecting, and delivering those supplies. The supplies included all classes as well as the miscellaneous supplies and bulk water transportation. Not included in this specific assessment were the functions that occur within a base or within a major combat operation. However, these elements drive the data for the distribution system and it is heavily dependent on the mission and scenario in which it is being employed. The amount of energy utilized on a base or within a major combat operation (MCO) is what stresses the supporting distribution system. Therefore, although for this assessment the bases and the MCO were not a part of the evaluation, they are an extremely important interface point.

The current execution of the operational capabilities associated with providing the resupply support to the base camps and combat operations in theater is done in a piece-part manner. There are multiple systems that are utilized to plan, track, protect, and deliver the supplies. Some of them are specifically designed for this mission, such as the asset visibility systems, while others are one of many missions, such as the Army’s mine resistant ambush protected vehicles (MRAPs) for convoy protection. Due to these facts, there is no true system of systems functionality that currently exists. However, there are many benefits to analyzing and providing a governing body to execute as a system of systems.

As the systems stand today, there is a piece-part effort to fulfill individual capabilities based on individual needs requests. There is a lack of understanding as to what the true implications of a solution are, or if it is even the right need being addressed. This is because there is no full picture of the mission to identify interfaces and interrelationships. If the Army were to begin treating operational energy as a system of systems then all aspects, not just the distribution systems, would be better understood. Furthermore, the Army would better understand the true implications of a system in terms of capability of the system of systems, as well as the ability to identify where the greatest ROI would be for development. In this sense the Army would no longer be playing catch-up to fill gaps, rather preemptively identifying areas of improvement to be prepared to deploy before the gap becomes an issue.

For instance, currently the largest resource consumed on a base in theatre is water, followed closely by fuel. In order to supply the base camp with the necessary supplies it requires a convoy, route clearance, and convoy escorts in addition to many man-hours to request, fill, track, load, and unload the orders. This adds up quickly in both man-hours, removing them from the fight, and dollars. Therefore, the cost of water and fuel that is used on the bases is significantly increased due to the fuel utilized in the convoys, air systems, and protection convoys used to get it to the bases and combat operations.

Bearing all of this in mind, the benefit of analyzing the distribution system as a system of systems would force the SE process to develop an architecture identifying the interfaces and interdependencies, create a means of analysis, develop use cases and scenarios for an entire theatre not a single system, and provide insight into more than materiel solutions that may improve or be impacted by new or modified solutions. For example, if a system is introduced that increases an MRAP by 5 mpg but has non-standard parts requiring additional spares to be transported in theatre and specialized maintenance requiring new training and two specialized mechanics on a base, the overall delta for savings may be a wash because of the excess stress put on the system of systems. If there is no integrated toolset or structure put in place to inform the decisions regarding these types of technology or system developments, the Army will continue to run in circles until it can understand the full impact of decisions and act upon them accordingly.

# **Research Questions**

Recalling the boundaries established for the research, seven primary questions have been identified for study in the literature review conducted.

1. What is encompassed in the system of systems for the distribution system for operational energy?

A proper assessment of operational energy distribution must begin with identification of the constituent systems that power Department of Defense (DoD) installations and platforms and their relationships.

1. What current capability gaps exist with respect to operational energy distribution?

The distribution system’s activities and functions require evaluation for inefficiencies, and threats to energy security. In some instances, the identification of a “gap” may need to be composed without supporting requirements or explicit statements of capability needs. In those cases, documentation must be cited to support the statement of the capability gap.

1. How would the operational energy distribution system be categorized in terms of System of Systems (SoS)?

There is widespread agreement that SoS can be characterized along a continuum spanning 1) virtual, 2) collaborative, 3) acknowledged, and 4) directed. Recent work in the field of SoS has defined five characteristics for assessing an SoS, these include autonomy, belonging, connectivity, diversity, and emergence. The recent research establishes patterns of SoS’ success relative to the assessment of those five characteristics in the context of the manner in which a particular SoS is governed.

1. What are the benefits and consequences of evaluating and treating operational energy distribution as a system of systems?

With this particular problem, it could be stated that there is an inversion in the architecture viewpoint compared to traditional assessment. For conventional platforms and installations, the flows of energy would traditionally be viewed as inputs and outputs to the primary system functions and the physical instantiations of systems and sub-systems. To put this SoS in proper context, it may be more appropriate to consider the sources and sinks/stores of energy as the primary SoS constituent system elements and the platforms and sites that are powered through that energy as outputs of the process.

1. What are the consequences of not addressing operational energy distribution as an SoS?

Presumably the DoD would stand a lesser chance of achieving operational energy goals without the focus that an SoS consideration and viewpoint provides. Specifically, what risks are inherent if an ad-hoc operational energy management approach is used when forecasting potentially unstable energy supply lines and sources of generation and price volatility? Also, if potentially increasing portions of budget are allocated to operational energy distribution what needed capabilities or operational readiness are reduced in that scenario? The recent land based conflicts U.S. armed forces have been involved in may not provide an accurate picture of operational energy distribution costs and logistics for potential future theaters of operation.

1. What are the challenges to treating this as a system of systems, both technically and programmatically?

The challenges regarding system development across domains presents a unique technical challenge in terms of interfaces, standardization, and integration. However, aside from the technical challenges there are major concerns with the implementation of a governance structure that will abide by the necessary laws and statutes while providing the required oversight and authority to enforce the system of systems methodology. Many challenges that may arise revolve around the perceived infringement of current tasks, dollars, and responsibilities. Thus the need to focus heavily on the governance implementation, especially for the SoS programs being implemented post-development and deployment (i.e., Operational Energy).

# **Literature Review and Methods**

The principle method that formed the basis for this investigation was a review of the existing literature that was publicly available. Having found numerous sources, the bulk of the information was drawn from four primary papers. These are discussed briefly in the following sections.

* **Energy for the Warfighter: Operational Energy Strategy (DoD 2010)**

This paper lays out a plan for operational energy that places an emphasis on energy security. Energy security is characterized by guaranteed access sufficient energy and the ability to safely deliver enough energy to sustain operations. Furthermore, this paper introduces an Assistant Secretary of Defense for Operational Energy Plans and Programs.

* **The Value of Energy Security from the Battlefield to the Base (Hammack 2012)**

Presented as an address to the House Armed Services Committee during the Second Session of the 112th Congress of the United States, a broad description was laid out for increased efficiency and a greater emphasis on renewable energy. The principal problem was identified as an over-reliance on fossil fuels and characterized by high cost, high risk to security, and high environmental impact.

* **Operational Energy Metrics: Increasing Flexibility While Reducing Vulnerability (Baer 2010)**

Fully burdened fuel cost was calculated and took into account energy reduction (efficiency), cost of moving energy (transportation), streamlining acquisition, and the impact to operational effectiveness. The overall goals were to increase flexibility and reduce cost by focusing on acquisition and force structure.

* **Analysis of Policy and Guidance Regarding Sustainability (Kinnevan 2011)**

With a focus on sustainability, this source focused on existing policy and doctrine supporting both sustainability and environmental considerations, and attempted to link these to contingency operations. This source was unique in the emphasis that it placed on environmental concerns, acknowledging the link between environmental impact and sustainable energy operations.

# **Data Collection and Analysis**

The focus of the data collection was on reports, white papers, requirements documents, and other secondary research supporting the Operational Energy concept. Once the information was collected it was parsed into the appropriate categories to support the proposed research questions.

## ***Research Questions addressed***

Due to the constraints of time available and the resources, only two of the six research questions were evaluated. The two questions were chosen because of the benefit the SoS would have on them, as well as the merit to the assessment of the system. The remaining questions are suggested as follow-on work.

*What current capability gaps exist with respect to operational energy distribution?*

According to the Operational Energy Strategy (DoD 2010) the following gaps exist:

* Moving large volumes of fuel for military operations entails logistical and tactical risks and challenges, and it can also be costly.
* FY 2007 in Iraq and Afghanistan, a total of more than 3,000 Army personnel and contractors were wounded or killed in action from attacks on fuel and water resupply convoys.
* According to the United States Transportation Command (USTRANSCOM), air delivery is 10 times as expensive as ground delivery.
* DoD currently lacks sufficient data on and analysis of operational energy use to manage consumption effectively.
* Current patterns of national and military energy supply, specifically of oil, carry strategic consequences ranging from effects of procuring and moving large volumes of fuel through a theater of operations to the geopolitical effects of growing global demand for oil. This increases concentration of supplies, and damages the environment.
* Current energy infrastructure remains vulnerable to disruption from hazards including weather, natural disasters, human error, maintenance shortfalls, equipment failures, and attacks on infrastructure, including cyber attacks.
* By the end of 2010, Defense Logistics Agency (DLA)-Energy was moving 40 million gallons of fuel per month into Afghanistan alone.

The gaps identified point to a number of issues that must be addressed to address operational energy from a more holistic viewpoint. The first issue is that of data collection to support analysis on consumption. Existing information points to several priority situations. One is the age of the Army’s legacy systems. Foremost among these aging systems is tactical generators. As bases have become widespread, the relative inefficiency of fielded generators compared to current technology has greatly increased the number of tactical convoys needed to sustain operations. This is also compounded by the challenges associated with heating and cooling of temporary assets such as tents in the current theaters of operation. As stated, some information is available, but governance of the system of systems that delivers the operational energy distribution capability requires better data. This is especially true with respect to analyzing the results from promising trials that have implemented higher efficiency generators and heating, ventilation, and cooling units and novel ideas for temporary living quarter insulation. Furthermore, governance, data, and information that affect both operational energy and contingency overseas basing needs to coordinate efforts and data needs to be shared in both domains. Many efforts are underway that deal with calculation of the fully burdened cost of fuel.

Another priority is the security and vulnerability of the logistical convoys delivering the operational energy. Development and fielding efforts have assessed introduction of safety measures onto tactical platforms that previously were fielded on combat platforms. That effort needs to be continued. Furthermore, the capability to generate energy locally at the forward-most bases will also enhance security through a reduction in the number of convoys in the most dangerous of areas.

*What are the challenges to treating this as a system of systems, both technically and programmatically? What Program Executive Organizations (PEOs) and what other organizations are involved?*

Currently there are many Program Executive Offices (PEOs) involved in the Operational Energy distribution system, including but not limited to PEO Combat Support & Combat Systems Security (CS&CSS), PEO Ground Combat Systems (GCS), PEO Command, Control and Communications-Tactical (C3T), PEO Enterprise Information Systems (EIS), and PEO JBD. One current effort is being lead by PEO CS&CSS through the Joint Operational Energy Initiative (JOEI). This effort is looking to evaluate the overall impacts to a theatres energy supply and demand, and investigating if given solutions can impact that energy delta. The current work is focusing specifically on the distribution system but will be integrating with the contingency basing effort to utilize the loads from the bases as inputs. The major output of this project is to develop a toolset and methodology by which existing and proposed technologies can be evaluated to determine the impact or benefit to the Army, in terms of energy concerns. This project is not proposing that the Army’s distribution system be managed as a SoS, but rather evaluated and provide a governance over it so that informed decisions can be made and implemented to benefit the overall Army. For instance, there needs to be a governance structure that has the authority and the funding to make decisions regarding upgrades, interfaces, technology development, and program cuts. This project is not the entire solution, but rather a small step to the achievement of the Energy key performance parameters (KPPs) to evaluate systems against as well as provide a toolset to inform decisions and future planning.

The governance structure needs to satisfy the SoS requirements, involve all elements of the the Joint Capabilities Integration and Development System (JCID) process from the US Army Training and Doctrine Command (TRADOC) to the Defense Information Systems Agency (DISA) to the Project Managers (PMs), and layout the necessary roles, responsibilities, and authorities (RRA) of all organizations to ensure compliance with laws and a complete understanding of the SoS decision making process.

First of all, an authoritative architecture would need to be maintained at the highest level, above all of the PEOs that would have a stake in the SoS. This would ensure that there was no unfair bias to one PEO or the other. Although the architecture would be maintained and owned by the system of systems engineering and integration (SoSE&I) organization, it would be the responsibility of the PEOs with systems involved to provided input though a task organization to ensure that the architecture was accurate and up to date, also, making sure that the needs of their PEO were represented in that architecture. Additional authorities would include the conflict resolution between interface touch points, sub-optimization decisions, direction of the SoS trades analysis, and trade objectives and criteria. Finally, it would help establish the objectives and schedules for the Army Modification Plans. The main purpose at the SoSE&I level is to align with the operational Army construct to deliver integrated, affordable, relevant BDEs in accordance with the Army Campaign Plan (ACP) & Army Forces Generation (ARFORGEN). All of these authorities are given to the organization that can be cross cutting of many different PEOs.

In order for the SoSE&I level authorities to be accurately and appropriately carried out, it will require input and guidance from the PEOs and PMs involved. Now, because it would be counter productive to have multiple chiefs and not enough Indians, a “trail boss” would be established. The trail boss would reside in an identified PEO and be the face to SoSE&I and the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)). The trail boss would have the responsibility to integrate platform level trades, define interfaces, boundaries, and parameters among all the necessary players, optimize solution sets across involved platforms, develop the lower level architectures to be rolled up and managed by SoSE&I, and provide funding estimates for recommended integration efforts to be decided on by SoSE&I. Most importantly this would provide the integrated analysis and recommendations for the path forward. This would involve many players across multiple PEOs and PMs who would come together to provide the necessary information for analysis and funding recommendations. Finally, they would be responsible for the development of the interfaces between the platforms. Currently, there is no governance or often even development of interfaces between platforms in different PMs.

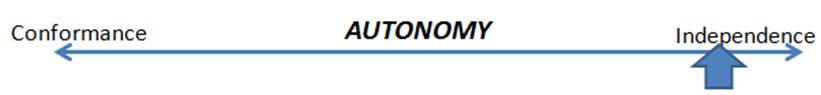
The individual PMs would remain responsible for the development and sustainment of the platforms within their portfolio. However, they would be responsible for participating in a task organization with the trail boss to provide the necessary information and requirements to ensure that the capabilities of the overall mission are met, along with the necessary requirements for their given platforms.

This governance structure is based off of a recommendation made by the Contingency Basing team for the CB project and future projects. By implementing a governance structure such as this, there is a flow up and down of information. There are authorities in place to analyze the individual components at the system level and the system of system of level. The requirements that are not being met are then flowed down through the overarching architecture to determine what systems need to be improved or developed to meet that capability, while simultaneously tracking the implications of those changes. It would provide an overarching analysis to identify what potential DOTmLPF elements are impacted, what logistical elements are impacted and secondary benefits or burdens are incurred so they can be addressed early.

## ***Characteristics Evaluation***

### **Autonomy**

Distribution of operational energy is considered to be highly independent. It is somewhat a function of the flexibility of the operational energy distribution system that maintains a high degree of autonomy within the system of systems. Many types of tactical platforms are available for transportation, from vessels to trucks to air assets. This provides operational flexibility to maintain a relatively reliable pipeline in a variety of operational environments and throughout increasing or decreasing threat levels in those environments. The adaptable nature of being able to contract out some of these services lets operational units rely on the local sources of supply and power generation when appropriate. Though this is critical for mission success in many parts of the world, this aspect further diminishes the Army’s ability to standardize tactical platforms and tactical processes, procedures, and doctrine. Higher degrees of conformance, with respect to mobile platforms and equipment that provides information services and climate control would help the overarching management of operational energy. The assessment of the autonomy characteristic is shown in Figure 2.



**Figure 2. Autonomy Scale and Assessment of Operational Energy Distribution.**

### **Belonging**

The pieces and parts that comprise the operational energy system were developed over a period of time and represent a System in the truest sense. Not all of them were originally designed to operate together, rather they were developed independently to fill the evolving needs of the Army.

That they were not all developed together as a System of Systems does not mean that they do provide the necessary functionality to the Army. In fact, they likely provide the functionality to support the technical requirements within the context of existing operational energy needs. Instead, this Family of Systems will lack the adaptability to conform to the Army’s evolving needs. Additionally, it will not likely be able to keep pace with recent goals for security, efficiency, and renewable energy.

A well-engineered System of Systems would be designed to work as a cohesive unit, providing efficient, flexible, and secure functionality in support of the Army’s needs for operational energy in a cost-constrained and rapidly changing environment. The assessment of the belonging characteristic is shown in Figure 3.

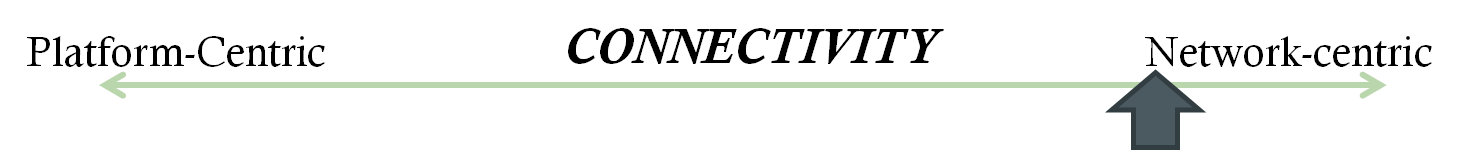


**Figure 3. Belonging Scale and Assessment of Operational Energy Distribution.**

### **Connectivity**

Existing operational energy supply lines tend to be minimally connected and are only minimally sufficient to meet supply chain demand. If supply routes are severed then fuel can often be re-routed or transported by an alternate medium (e.g., air or sea vs. land). This degree of connectivity results in significant increases in cost due to the logistics of sustaining remote operations in theater. Furthermore, much inefficiency is introduced as a result of a lack of alternative means of distribution. We desire to move from a less connected to a more connected state.

In a highly connected scenario, fuel could be routed among destinations on the basis of lowest cost. Fully burdened cost could be calculated for each node on a graph where each node represents either a supplier or consumer (or both) of operational energy. Then demand could be balanced by routing along the path of least cost in a way that mirrors power distribution in CONUS. The assessment of the connectivity characteristic is shown in Figure 4.

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**Figure 4. Connectivity Scale and Assessment of Operational Energy Distribution.**

### **Diversity**

The current operational energy situation is characterized by an over-reliance on fossil fuels. This dependence dictates, to a large extent, the terms of distribution. The distribution of fossil fuels in theater adds significantly to the cost of operational energy and puts warfighters in harm’s way in the process. We want to shift to a much more diverse operational energy portfolio.

By diversifying, we not only reduce the cost of distribution, but we also reduce the risk to operations due to disruption in the supply chain. By introducing other time-tested energy sources, as well as new emerging, and renewable sources, we eliminate a key vulnerability. With no single point of failure for operational energy, warfighter functions can continue to be largely supported even under austere or adverse conditions. The assessment of the diversity characteristic is shown in Figure 5.

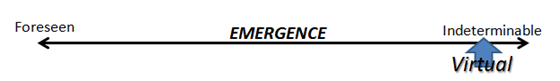
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**Figure 5. Diversity Scale and Assessment of Operational Energy Distribution.**

### **Emergence**

The operational energy distribution system is assessed to be highly indeterminable upon concluding the literature review. One reason for this is the volatility associated with the energy markets affecting future growth in price. It is difficult to project the direction of energy price given that the DoD’s demand may move in either direction going forward based on the potential conflicts (or relative lack of or reduction in conflicts) in the future. As noted in the Operational Energy Strategy: Energy for the Warfighter source document, the types of operations to be undertaken are unknown but a subject for many planning activities. Guidance exists to influence that planning to consider the energy stability and security for future operations. That is still a difficult forecasting task when the amount of future local supply and local power generation capabilities are undetermined, and the security of local supply is weighed as a risk. Even the amount of and types of future domestic energy source extraction and production are not known. As pointed out in the House Armed Services Committee (HASC) statement made by the Assistant Secretary of the Army for Installations, Energy, and Environment, numerous investments are being made in science and technology toward energy efficiency, and renewable energy. Some early trials are proving successful, but there is uncertainty in knowing which new technologies within the portfolio will succeed in being deployed widely. The candidate technologies that succeed will determine the necessary interfaces between the constituent systems and platforms and the type of new infrastructure and infrastructure modifications that will be required to support the revised and more efficient operational energy distribution system of systems in the future.

There are also some foreseen emergence properties that are determined by future limitations on budget narrowing and the possible future technologies that investment will be directed toward. Furthermore, efforts are underway to steer operational energy governance toward a more centralized approach. Among them is the establishment of an Assistant Secretary of Defense for Operational Energy Strategy for the DoD, and the Joint Operational Energy Initiative (JOEI) led by PEO CS&CSS and the Tank Automotive Research, Development and Engineering Center (TARDEC). The assessment of the emergence characteristic is shown in Figure 6.



**Figure 6. Emergence Scale and Assessment of Operational Energy Distribution.**

# **Conclusions**

Initial conclusions regarding the Operational Energy effort are that current efforts are insufficient to meet the needs of the Army. The United States possesses a military that requires capabilities provided by the integration of many systems across many functional areas, and yet develop those systems in a stovepipe. Therefore, it is critical to begin assessing, developing, integrating, and governing these capabilities from a system of systems perspective to enable the evaluation of an operational capability as opposed to a single system.

Operational Energy is a much larger issue that what has been analyzed and discussed in this analysis. However, many of the lessons learned and the evaluation of the SoS characteristics can be applied to the other major elements of the OE effort. Therefore, focusing on the distribution system and its interfaces into Contingency Basing and major combat operations, it was determined that this virtual system needs to have a governance and systems engineering structure put in place to begin moving it into more of a collaborative or acknowledge SoS.

Some of the major concerns with not evaluating this as a SoS and continuing to allow the operations of the logistical systems in the current way include increased cost, increased consumption of resources, lower operational readiness, and higher causality levels. By utilizing the tools available, emerging initiatives and a new governance structure to drive the development and integration of systems from the top down with the operational capability as the end goal, as opposed to the single system, the Army can begin to identify and rectify issues up front and early. In addition, they can influence future technology development, inform decisions regarding budgets and out year funding for individual programs and PMs, and provide insight into the necessary provisions for the logistic community to provide better support to the front lines while minimizing cost and the impact to the mission.

Specifically for OE, it was determined that there are current efforts that are chartered to evaluate the impacts of technology implementations on the overall energy concerns of the AOR. This will provide insights into secondary impacts caused by unforeseen issues due to interdependencies amongst systems. Additionally, it will provide data to identify what the support requirements, and life cycle requirements of a single change would be and thus could support the implementation of an Operational Energy KPP. Many times the performance and cost of a system are the main focuses of the development of that system, which is understandable. However, many times those assessments are incapable of extending beyond the current time frame and don’t take into consideration impacts on elements outside of the scope of the systems direct design impacts such as size, weight, and power (SWaP).

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