Leveraging Enterprise Architecture to Enable Integrated Test and Evaluation Sustainability

by

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B.S. Systems Engineering, United States Military Academy, 2005

Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

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Abstract

An analysis was performed to investigate how enterprise architecting methods can be applied to an integrate test and evaluation enterprise and make it a more sustainable enterprise to provide continuous value in the face of an evolving DoD landscape. Enterprise sustainability is the ability of an enterprise to maintain economic viability through optimal resource management and preservation over an extended duration. Through the application of the eight lenses of enterprise architecting, it was found that a more holistic understanding of a Major Range and Test Facility Base (MRTFB) enterprise's current state could be achieved. This approach also supported identifying gaps that exist between the ability of the current-state MRTFB to deliver value and the value delivery that is required by its key stakeholders. The importance of expanding the information view of enterprise architecting to encompass the entire enterprise infrastructure was also studied. Through the expansion of the information view to an infrastructure view, a more complete depiction of the MRTFB enterprise was achieved.

The specific importance of the energy infrastructure to a sustainable enterprise was also explored. Through the application of enterprise architecting, the interrelations between the energy infrastructure and the other views, such as processes, services, and knowledge, and the other supporting infrastructure components, such as facilities, land, physical assets, communication networks, and IT networks, can be established. It was found that the energy infrastructure is a core enabler for our technology-based society, and coupled with the current societal focus on green and sustainable energy provides a focal point for enterprises to leverage and initiate transformation efforts to align the energy infrastructure with larger enterprise strategic objectives.

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Chapter 1 – Introduction

1.0 - Research Motivations

The service members of the U.S. armed forces, its soldiers, marines, airmen and sailors, make up the frontline in the defense of the United States. To enable service members to best protect the United States through the execution of its National Security Strategy, the Department of Defense (DoD) must continue to ensure that its armed forces are the best equipped, trained, and motivated fighting force on the globe. The U.S. DoD has developed a robust, phased approach to system acquisition to equip its forces which can be both time consuming and costly. Economic realities and the ever-changing nature of combat will always motivate the DoD to find more efficient and effective ways of acquiring equipment.

In 2010, Under Secretary for Defense for Acquisition, Technology and Logistics Ashton B. Carter painted a picture of the situation within the Defense Acquisition and his resolution to transitioning to a leaner, more sustainable solution. The products and platforms, or systems, which warfighters use can be extremely costly to design, manufacture, field and sustain. From 2010 to 2015, $2 trillion was allocated to support DoD contracts and of this greater than 50% of the annual budget was allotted for acquisition efforts (Carter, 2010). Total Ownership Costs (TOC) are defined as "all costs associated with the research, development, procurement, operation, and decommissioning of an individual weapon system over its full life (US Naval Air Systems Command Total Ownership Cost, 2009). For a typical DoD system, the TOC is allocated with 30% for acquisition costs and 70% Operations & Maintenance (O&M) costs (Carter, 2010). The system acquisition phase of a program, even though less than one-third the cost of the TOC of the system, solidifies the follow-on O&M costs required for sustainment, because the early phases of a program define the level of training and personnel support required to operate the system and the levels of support equipment, consumables, and spares required to sustain the system upon fielding. A clear understanding of the systems functional and performance capabilities early in the acquisition process ensures that TOC and system capabilities meet the warfighters' requirements and expectations.

Even with the heavily regulated approach to DoD acquisition, which is intended to ensure a more controllable, methodical approach to system development, significant challenges can exist. A U.S. House of Representatives Armed Services Committee (ASC) review conducted in 2010 clearly presented some quantifiable examples of the cost and schedule challenges experienced across various information technology (IT) acquisition program. Of the programs review, only 16% of the programs were completed on time, 31% were cancelled prior to completion and 53% of the continued programs resulted in late deliveries that exceeded the program budgets by more than 89%. For the programs that reached completion, only 61% of the original capabilities specified for the products were actually delivered as part of the final products (U.S. House Of Representatives, 2010, p. 17).

Test & Evaluation (T&E) is an important component of the acquisition process and "reduces technical risk and increases the probability of a successful program" (Defense Acquisition University, 2011). A Defense Science Board evaluation indicates that roughly 50% of all programs completing Initial Operational T&E (IOT&E), which typically occurs in the latter half of the acquisition process, were not evaluated as operational effective or suitable. These findings report that "suitability failures are as high as 80% for some commodities" (Adolph, 2008). Shortcomings or errors identified at this stage in the process are critical, because they lead to either significant rework which result in additional program cost and schedule overruns or in a system being fielded that does not provide its intended value to the warfighter. Adolph (2008) also indicates that the root cause of these failures are complex and stem from major changes over the preceding 15 years, which includes acquisition reforms that eliminated military specification and standards, shifted towards Commercial-off-the-Shelf (COTS) components, deemphasized importance of reliability, and reduced government oversight of contractor-performed T&E. Additional focus on spiral product development, increased system complexity, and initiation of Systems of Systems (SoS) acquisition approach, as well as a significant reduction on government workforce within T&E have also created a cost and schedule strain on the acquisition process (Adolph, 2008).

The Weapon Systems Acquisition Reform Act (WSARA) of 2009, Public Law 111-23, was implemented by President Barack Obama with the purpose "to limit cost overruns before they spiral out of control" (Obama, 2009). The resulting Directive-Type Memorandum, DTM

09-027, amended the DoD acquisition policy to implement WSARA and to attempt to employ more spending oversight and control throughout the acquisition process through identification of cost risks earlier in the process, guarantee a thorough Analysis of Alternatives, improving cost assessments and analysis and initiating programs with realistic baseline budgets and schedules (Carter, 2009). In a September 14th, 2010, memorandum to acquisition professionals, Mr. Carter provided his "guidance for obtaining greater efficiency and productivity in Defense spending" which is expected to reduce acquisition budget requirements by 25% over the next five years (Carter, 2010).

The execution of these laws and directives primarily focused on changing policy at the top level of the acquisition community, with little to no direction as to how the policy will be executed by the T&E organization(s) within the acquisition community to reduce and manage the technical risk that drives program cost and schedule overruns. Other important factors, such as the implementation strategy for the laws and directives, the organization, their personnel and critical resources, and the knowledge and processes which are required to execute the policies and that enable the acquisition and sustainment of systems are not clearly addressed by these directives or are being addressed in a piecemeal fashion at various levels of the T&E community.

1.1 - Thesis Topic and Research Questions

The purpose of this research effort is to investigate how enterprise architecting (EA) can enable integrated T&E sustainability to meet an evolving DoD T&E needs. EA is a "strategic approach which takes a systems perspective, viewing the entire enterprise as a holistic system encompassing multiple views such as organization view, process view, knowledge view, and enabling information technology view in an integrated framework" (Nightingale & Rhodes, 2004, p. 1). Challenges of the DoD T&E enterprise that are addressed by this research include continuous adjustment of efforts to rapidly align with the numerous, complex system test and evaluation requirements of DoD acquisition process while facing stringent policy implementation, budgetary limitations, and reduction in personnel and aging support infrastructure. Key DoD T&E stakeholders indicated that transitioning to a sustainable T&E enterprise is the top strategic objective for the enterprise, and this objective drives this thesis. A sustainable enterprise is defined as an enterprise which possess the ability for "maintaining

economic growth and viability while meeting concerns for environmental protection, quality of life, and social equity" and "having optimal resource preservation and environmental management over time" (Allen & Moses, 2001, p. 5). An EA approach uses interviews and research of publically available documentation and reports to determine the current state of the enterprise and to identify the key stakeholders of the enterprise. Potential gaps between the enterprise and its strategic objective, specifically in a typical DoD T&E enterprise, were identified as they relate to the enterprise value delivery to its key stakeholders. The EA approach uses various lenses to view an enterprise to identify interrelations between the various facets of an enterprise. Further investigation into the infrastructure view of the enterprise was investigated to determine how the energy infrastructure can enable the transformation of the DoD T&E enterprise into a sustainable enterprise which continues to deliver value to their key stakeholders over the long term.

The following research questions were investigated though the analysis of a DoD T&E enterprise:

- How can enterprise architecting be used to holistically analyze a DoD T&E enterprise to identify gaps between its current state and its desired state based on its strategic objective, to becoming a sustainable enterprise?
- How does viewing an enterprise through an infrastructure lens, specifically energy infrastructure, better enable EA to support enterprise transformation to a sustainable enterprise and value delivery to its key stakeholders?

1.2 - Thesis Roadmap

Chapter 1 of this thesis provides an overview of the motivation for this research, along with detailing the research questions and roadmap. Chapter 2 presents a literature review that provides background information on T&E's role in the DoD acquisition process and the various roles within the DoD T&E enterprise. This chapter sets the background for the research methodology that is used in this research effort by portraying the information required for a clear understanding of the current state of the enterprise, how the enterprise creates value, what is necessary to transform the enterprise, and when transformation is required. Chapter 3 conveys the research approach of enterprise architecting methods to the DoD T&E enterprise to provide a clear depiction of the enterprise stakeholder analysis, including the identification of its

stakeholders, their values, and the saliency of the stakeholders. Chapter 4 provides the results of the data collection which defines the *as-is architecture* of a representative T&E enterprise within the DoD, for which a transformation strategy would be developed to reach a desired *to-be architecture*. The enterprise is viewed through various lenses to create a holistic understanding of current enterprise and to identify gaps between the as-is and the to-be architecture, that will better meet the key stakeholders' needs. This chapter also investigates how the infrastructure view builds upon the current EA information view to provide greater insight into the enterprise. Chapter 5 investigates how a notional *could-be architecture* aligns the energy infrastructure of the enterprise to better provide value to its key stakeholders to meet the enterprise's strategic objective. Chapter 6 summarizes the findings from using enterprise architecting to enable integrated T&E sustainability to meet the evolving DoD landscape. It defines the next steps towards implementing an energy infrastructure solution that supports transforming the enterprise, and it recommends future research opportunities to support transformation of the DoD T&E enterprise and a deeper understanding of stakeholder analysis application to support EA.

Chapter 2 – Literature Review

2.0 - The DoD Acquisition Process

The Defense Acquisition System (DAS) (US Department of Defense, 2003, p. 3), states

4.1. "The Defense Acquisition System exists to manage the nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. The investment strategy of the Department of Defense shall be postured to support not only today's force, but also the next force, and future forces beyond that."

4.2. "The primary objective of Defense acquisition is to acquire quality products that satisfy user needs with measurable improvements to mission capability and operational support in a timely manner, and at a fair and reasonable price."

The DAS defines the governing policies and principles that have been established for the defense acquisition system. The operations of the DAS are established by DoD Instruction 5000.02. This instruction describes the Defense Acquisition Management System in Figure 1, which implements the policies and principles of the DAS. According to *The Defense Acquisition University* (DAU), "the Defense Acquisition Management Framework lays out an event-based process where acquisition programs proceed through a series of milestones associated with significant program phases"(Defense Acquisition University, 2011). An acquisition program must proceed through a deliberate, phased approach of technology maturation, definition of military needs and operational requirements, and system design and development, including T&E, to ensure that the once fielded, systems provide the best value while meeting the needs of warfighters.

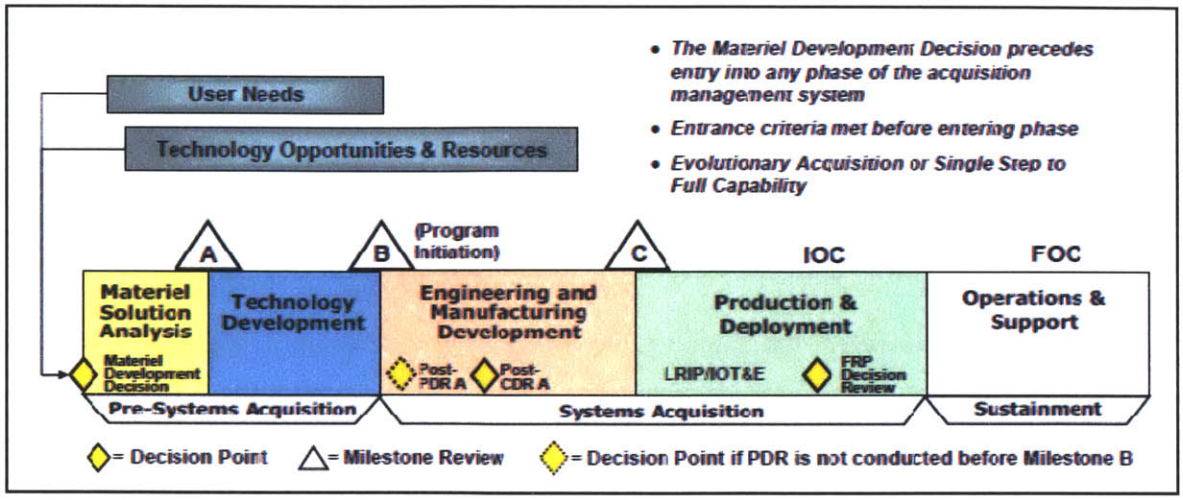

Figure 1: Defense Acquisition Management System (US Department of Defense, 2008)

This system is implemented via a process that begins with materiel solution analysis and technology development, which are the process steps during the pre-systems acquisition stage. The formal acquisition stage includes the engineering and manufacturing development and the production and deployment phases. The final stage includes operations and support which comprise the sustainment stage a system's life cycle. Milestones A, B and C are major approval milestones in the process at which approval must be provided for the process to continue. The decision points are gates within the process at which the approval must be granted for the system acquisition process to continue. As a program matures, beyond the system development efforts and into the fielding and sustainment efforts, such a parts sparing, maintenance capability, training, the Initial Operational Capability (IOC) and Full Operational Capability (FOC) achievement is declared. These declarations note the ability of the system to be fielded and meet the operational and sustainment needs of the warfighters (Defense Acquisition University, 2011).

2.1 - T&E Role with the DoD Acquisition Process

T&E plays an important role in DoD acquisition process through the understanding technical risk and identification of problems early in acquisition life cycle and through provide verification and validation of the system. *The Defense Acquisition Guide* (DAG) states "test and evaluation is an integral part of the systems engineering processes of verification and validation. Test and evaluation should permeate the entire life cycle of an acquisition program and is also an

important tool to identify and control risk" (Defense Acquisition University, 2011, p. 256). Verification is the process by which the "ability of the materiel solution(s) matured system concept(s) [can] meet the capability needs" (Defense Acquisition University, 2011, p. 219). Verification, a quality control process, ensures that the stated capability and/or functionality from the component up to a SoS level meet the requirements as dictated by the product specifications. Validation, a quality assurance process, ensures that the resulting system's capabilities and functionality enable the desire operational performance to meet the Warfighters' needs.

The DoD is comprised of multiple organizations which reside at the Office of the Secretary of Defense (OSD) level that are chartered to provide governance for the T&E efforts in support of DoD acquisition efforts. These entities provide high-level governance of the T&E organizations of each branch (Army, Navy, Marines and Air Force) to enable T&E efforts "to provide knowledge to assist in managing the risks involved in developing, producing, operating, and sustaining systems and capabilities" (Defense Acquisition University, 2011). The OSD-level T&E entities and their charters are summarized in Table 1.

Table 1: OSD Level T&E Organizations and Roles & Responsibilities

Organization	Roles & Responsibilities
Test Resource Management Center (TRMC)	Development of *DoD Strategic Plan for T&E Resources*
	Oversight of test and evaluation infrastructure including major range and test facility bases (MRTFBs)
	Certification of service test and evaluation budgets
Director, Developmental Test & Evaluation (DDT&E)	Generation of DoD policy and guidance for the conduct of developmental test and evaluation (DT&E)
	Oversight of developmental test and evaluation (DT&E) activities in support of major defense acquisition programs (MDAP) including the test and evaluation management plan (TEMP) and the test and evaluation strategy (TES)
	Develop developmental test and evaluation (DT&E) technical workforce
Director, Operational Test & Evaluation (DOT&E)	Generation of DoD policy and guidance for the conduct of operational test and evaluation (OT&E)
	Oversight of operational test and evaluation (OT&E) activities in support of major defense acquisition programs (MDAP)
	Develop operational test and evaluation (OT&E) technical workforce
Joint Interoperability Test Command (JITC) Resides within Defense Information Systems Agency (DISA) Test & Evaluation Office (TEO)	Generation of DoD policy and guidance for the conduct of test and evaluation for information and communications systems
	Oversight of DoD information systems and net-centric test and evaluation activities
	Focused on information flow between systems, specifically information and communications systems

"T&E provides knowledge of system capabilities and limitations to the acquisition community for use in improving the system performance, and the user community for optimizing system use and sustainment in operations. T&E enables the acquisition community to learn about limitations (technical or operational) of the system under development, so that they can be resolved prior to production and deployment" (Defense Acquisition University, 2011). T&E is integrated throughout acquisition process, as indicated in Figure 2. A T&E strategy (TES) and a T&E master plan (TEMP) are documents that define the details of how T&E will be conducted on a specific program. Various component and system level T&E events are performed throughout the acquisition process to ensure the required data collection and analysis

demonstrates the system aligned with meeting critical program milestone and review objectives. Though comprised of numerous events, the T&E effort is broken down into two main focuses, developmental test and evaluation (DT&E) and operational test and evaluation (OT&E).

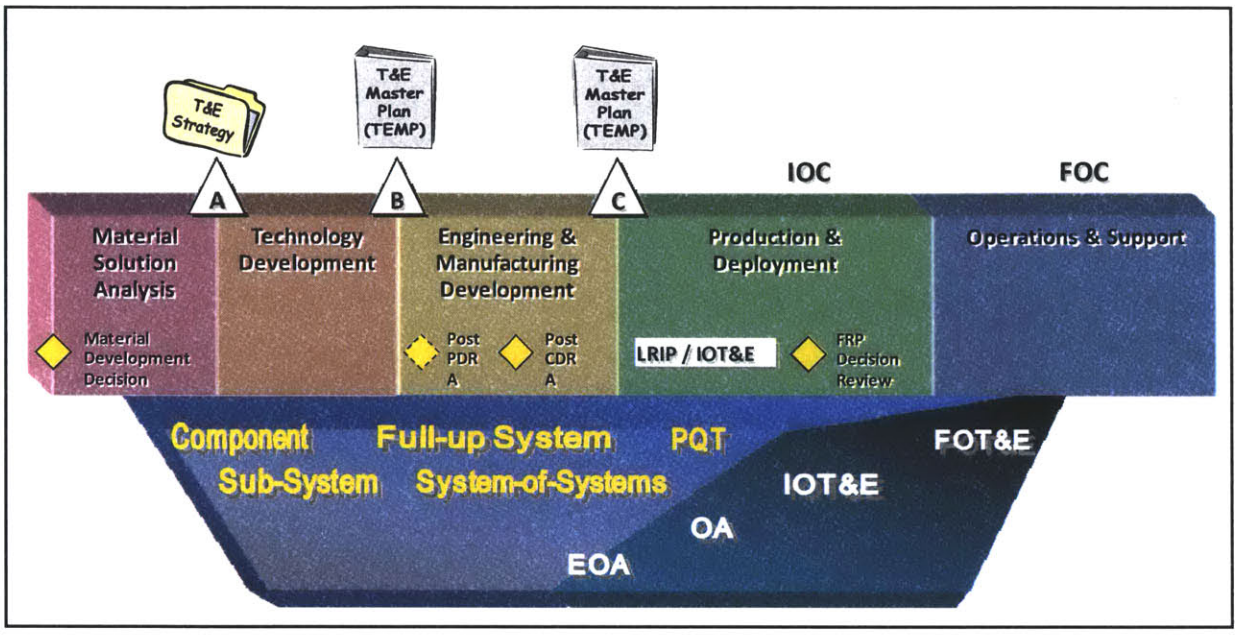

Figure 2: Pictorial View of T&E support to DAP (Myers, 2009)

As defined in the DAG, developmental testing is conducted to provide "verification and validation [data to support] the systems engineering process and must provide confidence that the system design solution is on track to satisfy the desired capabilities." This is performed through the collection and analysis of data pertaining to the ability to meet the technical performance parameters, the validation of models and simulations, and identification of technical risks and their associated mitigation efforts. Technical performance and system maturity evaluations are conducted in environments which are operationally relevant to the system. Validated models and simulations are used to aid "cost-effective combination of analysis, examination, demonstration, testing and evaluation" (Defense Acquisition University, 2011, p. 210). The DT&E efforts are conducted up through milestone C in support of certification that the system is ready to continue into operational testing (Defense Acquisition University, 2011). DT&E efforts include testing of components, sub-systems, systems, and systems of systems and production qualification tests (PQT).

Operational testing is "conducted to evaluate system operational effectiveness, suitability, and survivability" through the validation of systems operations in "realistic combat-like conditions" using a "production representative system" and using "threat or threat representative forces, targets, and threat countermeasures" with "representative typical users." This mantra of "test like we fight" is conducted to "determine the operational effectiveness and suitability of a system under realistic operational conditions" (Defense Acquisition University, 2011). This validation effort is used to ensure a more complete understanding of a system's capabilities that will be used in support of actual combat operations and to ensure a full comprehension of additional operational impacts that will be recognized during the fielding and sustainment of the system. OT&E efforts include early operational assessment (EOA), operational assessment (OA), initial operational test and evaluation (IOT&E), and follow-on operational test and evaluation (FOT&E). Additional live-fire test and evaluation (LFT&E) is also conducted on systems where missile firing occurs.

2.2 - Understanding the Enterprise, Value, and Transformation

An enterprise is a "complex, integrated, and interdependent system of people, processes, and technology that creates value as determined by its key stakeholders" (Nightingale & Srinivasan, 2011, p. 2). It is comprised of individuals working in unison performing linked efforts to meet a common purpose of delivering value(s) to stakeholder(s). A stakeholder, depicted in Figure 3, can be either internal or external to a particular enterprise and is considered as a critical part of the enterprise. A stakeholder is "any group or individual that can affect or that is affected by the achievement of the enterprise's objectives." The value that is delivered to the stakeholder must be of "particular worth, utility, benefit, or reward that [the] stakeholders expect in exchange for their respective contribution to the enterprise" (Nightingale & Srinivasan, 2011, p. 2). The interdependencies between internal and external stakeholders, processes, and technologies of an enterprise are often complexly integrated. The boundary between the enterprise and external organizations that influence the enterprise must be clearly defined so that the context in which the enterprise is viewed in clearly understood.

The enterprise's value proposition is a "description of the unique mix of products and service attributes, stakeholder relationships, and other intangibles that an enterprise offers its key

stakeholders" (Nightingale & Srinivasan, 2011, p. 257). The value stream is "the flow of products/services through [the enterprise's] processes which result in meeting customer needs. A Value Stream starts with raw materials or initial information or initial requirements [and] ends with the end-customer." (Lucero, 2002, p. 4). Understanding the value proposition and the value stream is critical to determining the ability of an enterprise to satisfy their stakeholders since an enterprise truly only provides value when a stakeholder receives the minimum value that they expect.

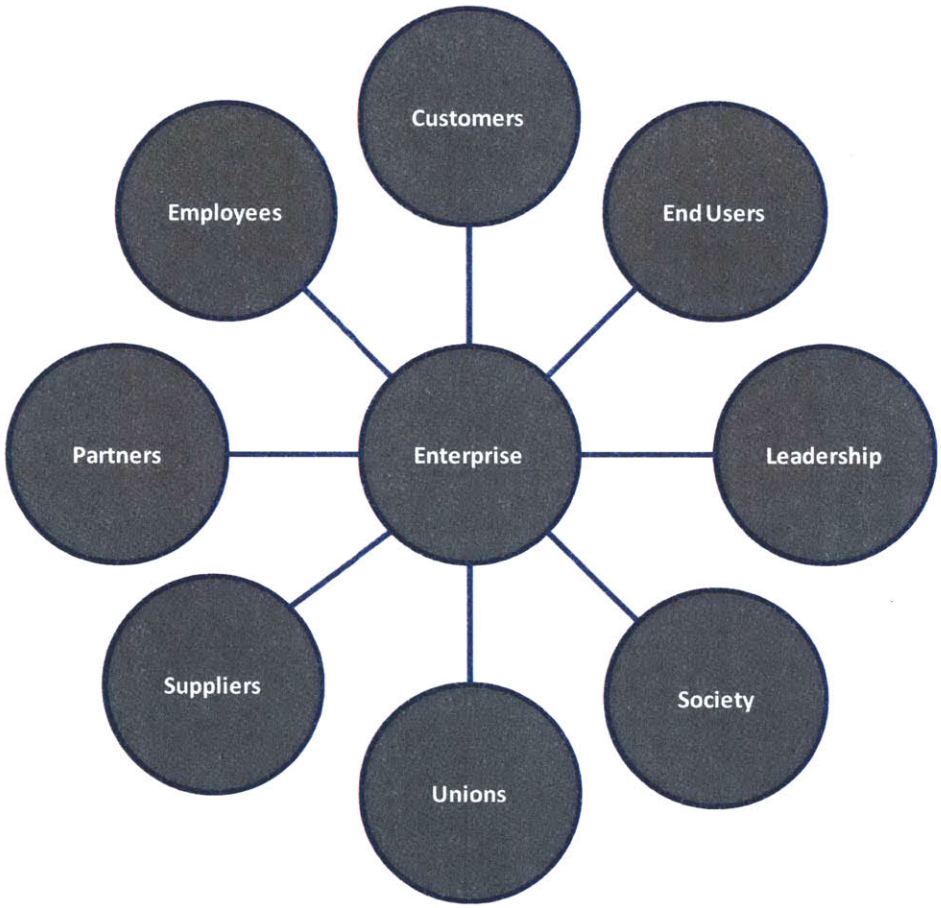

Figure 3: Generic Stakeholder Model (Nightingale & Srinivasan, 2011, p. 63)

The value delivered by an enterprise is often viewed more traditionally as a resulting product or service delivered to the end-user, but it is often comprised of less tangible substance, such as a position of authority within an organization. Due to the evolving nature of all enterprises and the environment in which they operate, their value proposition and value stream

continuously evolves, whether intentional or unintentional. Because of this, the identification of value, the enterprise's value proposition and their value delivery must continue to evolve with the changing environment for the enterprise to remain pertinent to its stakeholders. As noted by Murman and depicted in Figure 4, "Value identification, proposition and delivery are an iterative process leading to final value delivery to the stakeholders. The value stream must be evolved to continue to deliver value to the stakeholders for the Enterprise to remain relevant" (Murman, 2002). Value identification initiates the process by identifying the stakeholders and determining their needs. Value proposition is the step at which the enterprise determines how to meet the stakeholder's needs. Value delivery is accomplished when the actual value is delivered to the stakeholder.

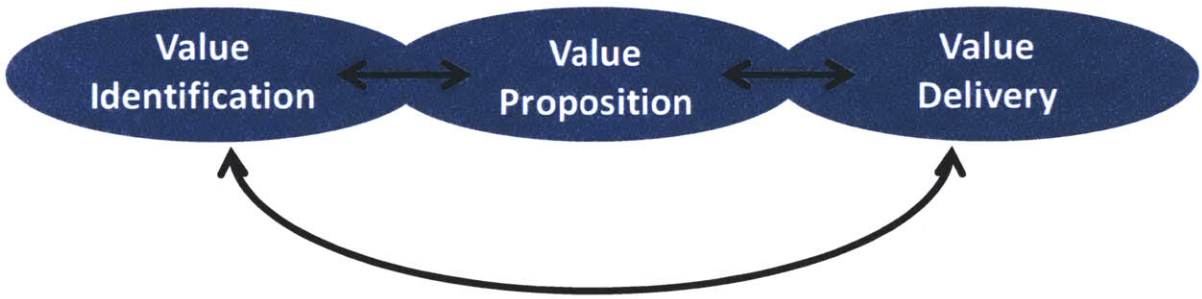

Figure 4: Value Creation Iterates and Adapts (Murman, 2002, p. 11)

This concept of value creation being iterative in nature and requiring continuous adaptation of the enterprise to remain relevant drive the need for change within the enterprise. In some instances, the change required can be managed by incremental improvements to realign an organization's processes, services, or products. This incremental improvement can typically be conducted within one facet of an organization, such as manufacturing processes. For example, lean and six-sigma processes have relied heavily upon for significant improvements that are driven by waste reduction and cutting of non-value added resources and processes (Nightingale & Srinivasan, 2011, p. 3).

However, when the requirement for more significant change arises within an enterprise, enterprise transformation is required. Enterprise transformation is "the taking of an enterprise from its current state to an envisioned future state, a process that requires a significant change in mindset, the adoption of a holistic view, and execution to achieve the intended transformation

goals and objectives" (Nightingale & Srinivasan, 2011, p. 2). According to Rouse and Baba (2006, p. 67), the determination of when fundamental enterprise change is required can be identified by looking at existing "challenges from technical, behavioral, and social perspectives." When challenges within an organization are visible from all of these various perspectives, enterprise transformation is required to implement fundamental change across an organization's functional boundaries and can affect their policy, strategy, processes, culture, and products. Rouse (2005, p. 279) notes that "enterprise transformation concerns change, not just routine change but fundamental change that substantially alters an organization's relationships with one or more key constituencies, e.g., customers, employees, suppliers, and investors. Transformation can involve new value propositions in terms of products and services, how these offerings are delivered and supported, and/or how the enterprise is organized to provide these offerings. Transformation can also involve old value propositions provided in fundamentally new ways." This method of using a holistic, systematic approach to analyze and transform an enterprise enables alignment of multiple facets, with oftentimes complex interrelationships, of the enterprise to improve the ability of the enterprise to deliver value to its key stakeholders.

Chapter 3 – Research Methodology: Enterprise Architecting

3.0 - Enterprise Architecting

As illustrated by Nightingale and Rhodes (2004, p. 2), "Enterprise Systems Architecting is a new strategic approach which takes a systems perspective, viewing the entire enterprise as a holistic system encompassing multiple views such as organization view, process view, knowledge view, and enabling information technology view in an integrated framework." Due to the complexity of today's enterprises and the issues they face, an engineering systems approach is better suited to study the "complex engineering of systems in a broad human, societal, and industrial context" as compared to more stove-piped approaches (Nightingale & Rhodes, 2004, p. 2). This approach of viewing an enterprise and its ability to deliver value as an engineering system closely parallels the product development process, as noted by Nightingale and Rhodes in Figure 5.

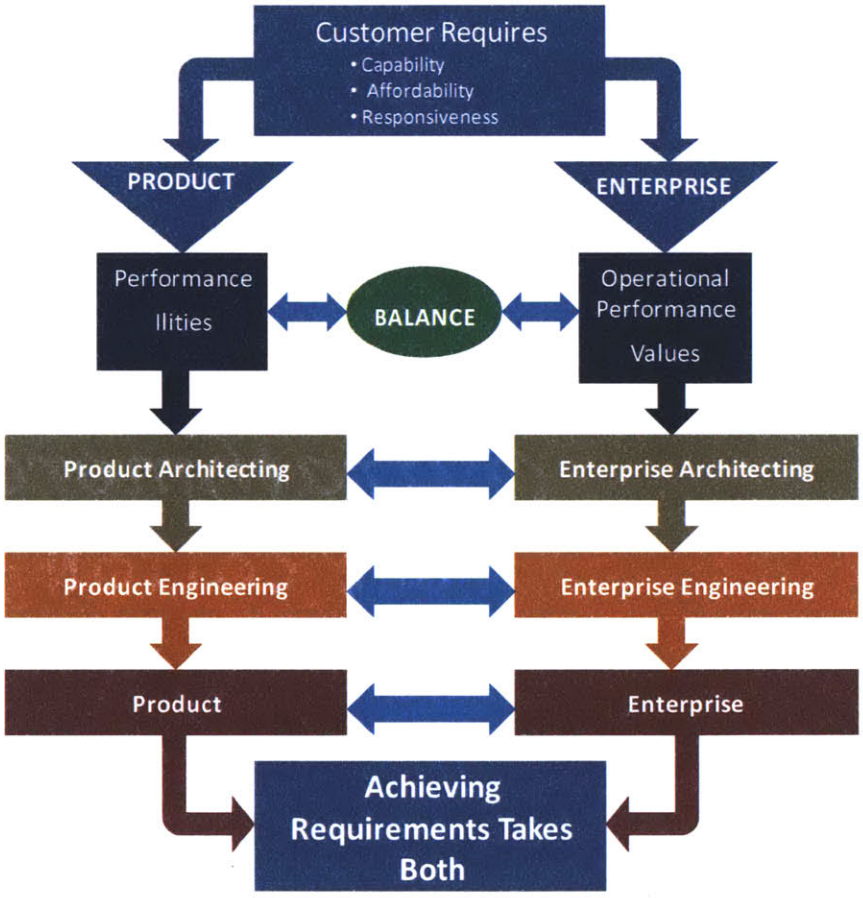

Figure 5: Parallels in Creating Products and Enterprise (Nightingale & Rhodes, 2004, p. 5)

As depicted in Figure 6, enterprise architecting is a phased approach used to define the current state, architect potential future states, select the optimal architecture as the future state, and institute a transformation to reach the desired future state. Similar to product design and development, defining the current state and requirements for the system are a most important first step. This includes understanding what value is to be delivered to which stakeholders, and then determining how it is to be delivered, with potential systems architected to meet value delivery requirements. An evaluation is conducted of these candidate systems, followed by the detailed design, or transformation, of the system to its desired end state. The process is monitored throughout to ensure that environmental changes are accounted for as the development progresses.

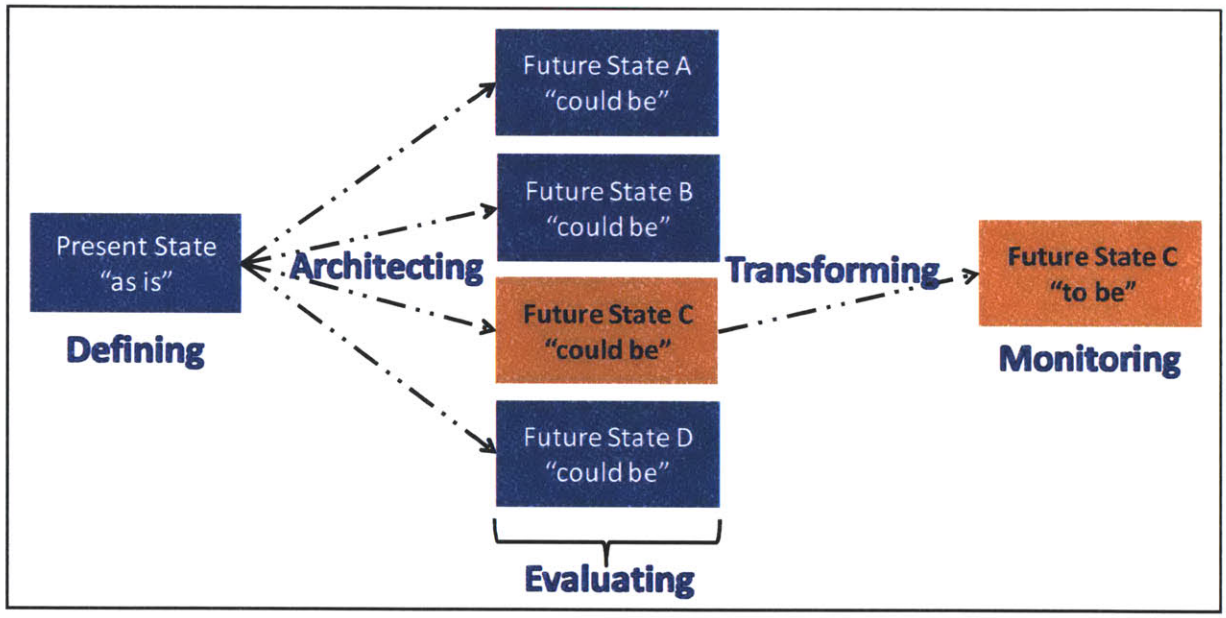

Figure 6: High Level Enterprise Architecting Process [Adapted from (Nightingale & Rhodes, 2011)]

An enterprise architect analyzes an enterprise and its current alignment to the enterprise's strategic objectives by viewing the enterprise through various lenses and their interrelationships as depicted in Figure 7. By viewing an enterprise as a system, through varying views and by understanding the current architecture of the enterprise, potential future enterprise architectures

can be defined and analyzed to develop a feasible path forward to reach desired end-state architecture of the enterprise.

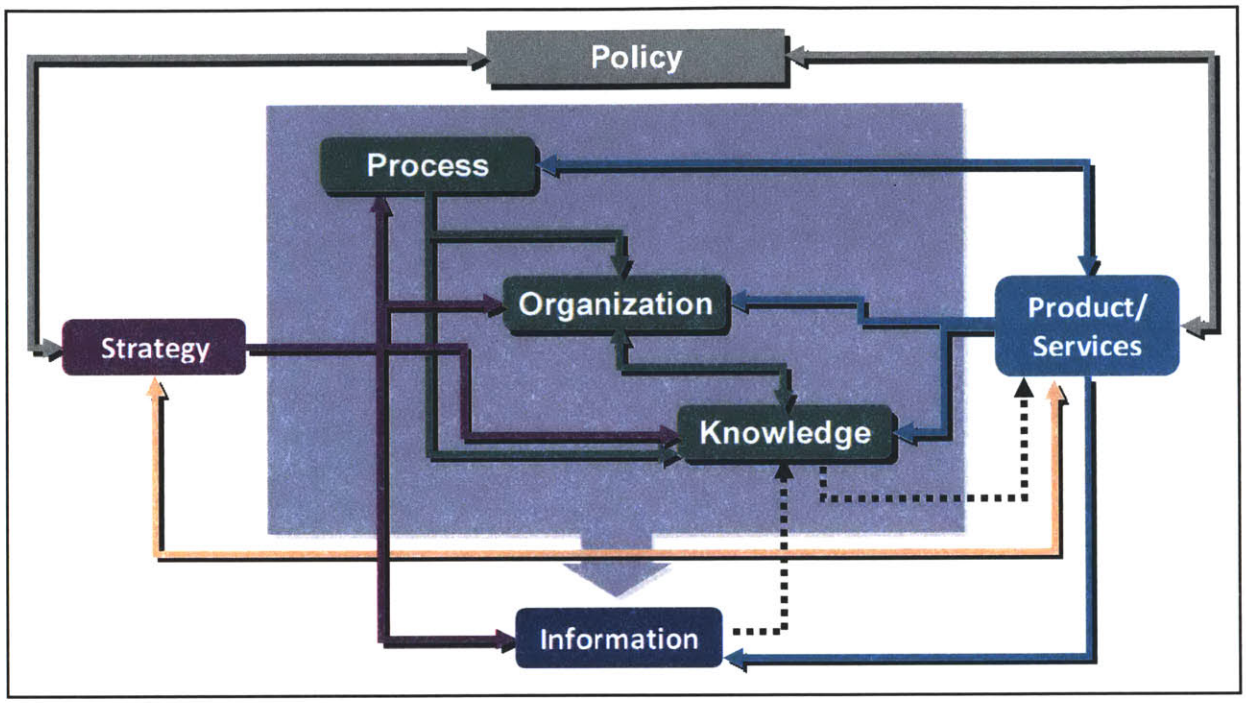

Figure 7: Generic Enterprise Architecture Eight Views and Interrelations (Nightingale, 2009, p. 6)

The eights views proposed by Nightingale and Rhodes, shown in Table 2, include strategy, policy and external environment, process, organization, knowledge, information, product, and services. Analyzing an enterprise through varying views and understanding their interrelations enables a more holistic evaluation of the current state of the enterprise, defining the as-is architecture. This is driven through the identification of the enterprise's key stakeholders and the understanding of how well the enterprise delivers value to meet the expectations of its stakeholders. By understanding where the enterprise is presently positioned, and more importantly, aligning its strategic objectives with the key stakeholders' expectations, possible future states, or could-be enterprise architectures can be defined. The evaluation of could-be architectures is facilitated through determining a set of evaluation criteria that is used to select a desired, to-be enterprise architecture for the enterprise.

Table 2: Enterprise Architecture View Descriptions (Nightingale, 2009, pp. 5-6)

Views	Descriptions
Strategy	Strategic goals, vision and direction of the enterprise including the business model; enterprise metrics and objectives
Policy	The external regulatory, political and societal environments in which the enterprise operates
Process	Core leadership, lifecycle and enabling processes by which the enterprise creates value for its stakeholders
Organization	The organizational structure of the enterprise as well as relationships, culture, behaviors and boundaries between individuals, teams and organizations
Knowledge	The implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise
Information	Information needs of the enterprise, including flows of information as well as the systems and technologies needed to ensure information availability
Product	Product(s) developed by the enterprise; key platforms; modular vs. integral architectures, etc.
Services	Services(s) delivered and or supplied by the enterprise, including in support of products

One way of determining an enterprise's ability to deliver value to its key stakeholders is though the *ilities*. Ilities are vital enterprise properties, as they can be used to define the long-term characteristics that are important to the enterprise, such as sustainability, adaptability, agility, and robustness to name a few. The properties "specify the degree to which [enterprises] are able to maintain or even improve function in the presence of change" (McManus, Richards, Ross, & Hastings, 2007, p. 2). The ilities can be used to provide evaluation criteria for the evaluation of could-be architectures.

A transformation strategy is developed to define the steps that the enterprise must undertake to improve value delivery to its key stakeholders and reach the desired, future state. Due to the oftentimes long durations required to transform an enterprise to its desired to-be state, continuous monitoring is required during and after the transformation phase of EA. This monitoring is important to identify adjustments required in the transformation strategy during and after its

implementation to ensure continuous alignment with inevitable changes within the enterprise and in the environment in which it operates.

3.1 - Research Approach to Defining the T&E Enterprise

The remainder of this thesis will focus on applying the EA approach to a DoD T&E enterprise. To enable a broader analysis to be incorporated into this research effort, a specific T&E enterprise is not pinpointed, but a typical as-is architecture, strategic objective and gaps are defined, and gaps between the two are identified using key stakeholders which are common across DoD T&E organizations. The research method for this effort uses a triangulation approach, as depicted by Srinivasan in Figure 8. This approach gathers information by reviewing research literature, interviews and site visits, and collecting available data in raw format, and triangulates the information from these three sources to synthesize a clear understanding of the enterprise's stakeholders, its as-is state, its strategic objectives, and the existing gaps between the as-is state and strategic objectives of the enterprise. This approach results in an accurate, generic representation of the as-is enterprise architecture for a typical DoD T&E enterprise and allows the identifying common gaps that must be resolved to reach their strategic objectives. The evaluation of could-be states and the development and implementation of the transformation strategy requires additional effort to be worked in collaboration with a specific T&E enterprise, which is not being addressed in this research effort. Specifically, a formal EA team should validate and agree to evaluation metrics that will be used to select an optimal to-be architecture. An EA team should be comprised of members of key stakeholders who are empowered and can influence the transformation stage of EA.

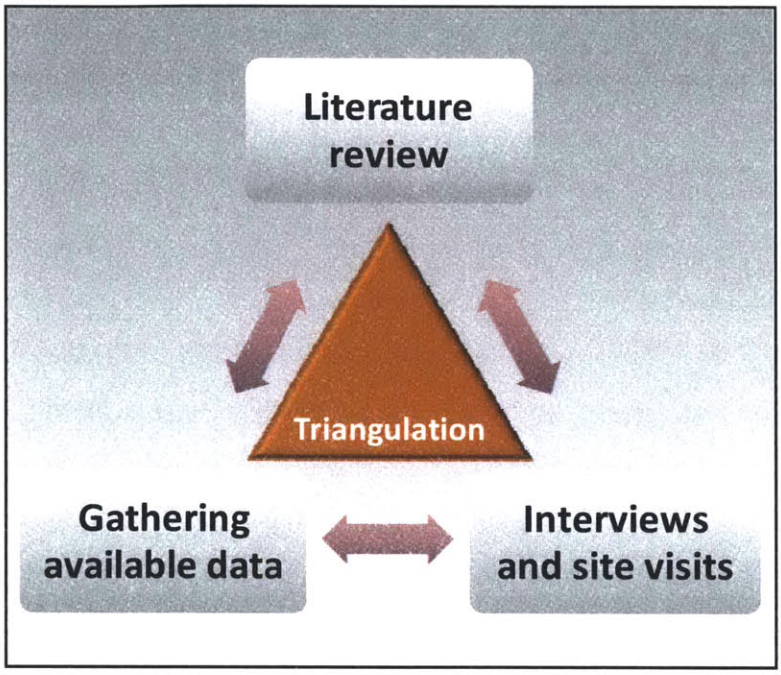

Figure 8: Triangulation Approach to Research Analysis (Srinavasan, 2011)

To validate this approach of applying EA to a generic DoD T&E enterprise, the commonalities and differences between the T&E enterprises within each of the military branches must be understood. All DoD T&E enterprises must conform to the same set of governing policies and oversight as defined in the DAS and the guidance outlined in the DAG. As discussed in the literature review, the DoD establishes overarching T&E policy at the OSD-level through DDT&E for developmental testing and through DOT&E, for operational testing. *The DoD T&E Strategic Plan for T&E Resources* and funding, as well as T&E infrastructure oversight, is provided through Test Resource Management Center (TRMC). Branch-level T&E enterprises are responsible for adhering to OSD-level mandates and policy. The Army Test & Evaluation Center (ATEC), the Marine Corps Operational Test & Evaluation Activity (MCOTEA), the Naval Operational Test & Evaluation Force (OPTEVFOR) and the Air Force Operational Test & Evaluation Center (AFOTEC) establish branch-level policy and guidelines and coordinate with the appropriately T&E OSD-level organizations to ensure compliance with their mandates.

To further enable a successful application of EA to be applied to a generic DoD T&E enterprise, the enterprise must be viewed from a systems perspective. This allows design and

development difference details derived from branch specific analyses, to be incorporated into the could-be, to-be and transformation strategy, or in the event a formal EA team is established, be left for follow-on efforts by specific T&E enterprises. Malan and Bredemeyer (2002, p. 48) prescribe taking a minimalist approach to systems architecting, the architecture should "guide and constrain, imposing [the] best ideas and lessons learned on designers and developers" by "sort[ing] out [the] highest-priority architectural requirement" while "keep[ing] [the] architecture decision set as small as possible." Their approach, as depicted in Figure 9, implies the role of enterprise architecture is to provide high-level guidance to ensure holistic understanding and alignment of the enterprise to reach its strategic objective. Malan and Bredemeyer (2002, p. 46) accurately note that "the bigger you make the architecture—the more all encompassing, the more ambitious, no matter how well-intended—the harder it is for the organization to absorb. The organization will be less likely to embrace a large architecture." This allows the design details required for the transformation strategy to be defined and executed by those who are better suited to make the decisions, those empowered by a formal EA team to drive change within the lower levels of the enterprise.

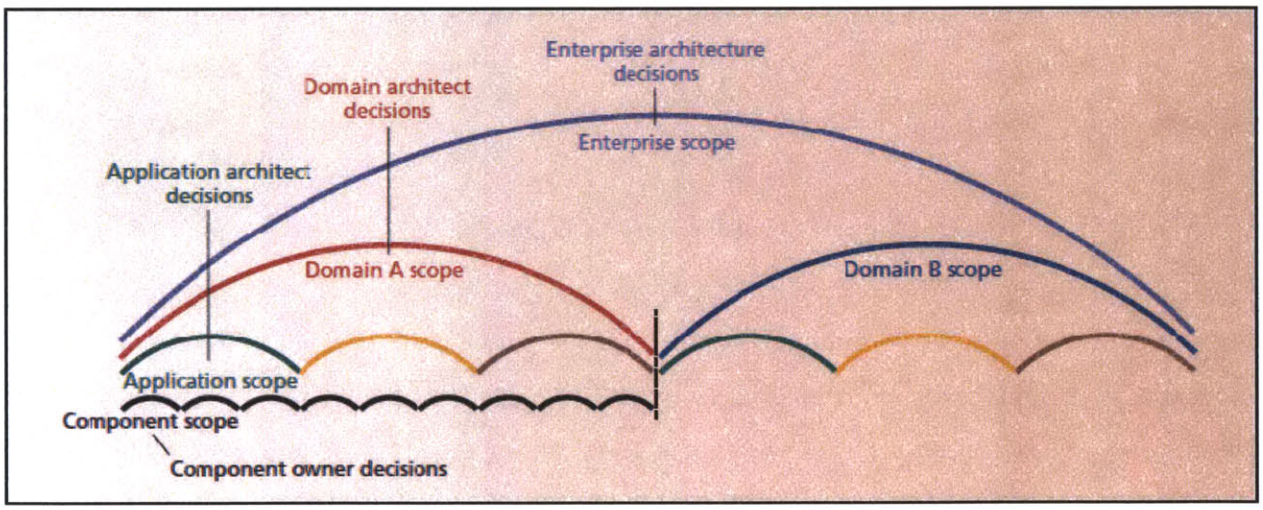

Figure 9: Architectural Levels of Scope (Malan & Bredemeyer, 2002, p. 46)

As identified from interviews with key enterprise stakeholders, the strategic objective for the DoD T&E enterprise is to become a sustainable T&E enterprise which operates efficiently and effectively in the evolving DoD landscape. Leveraging enterprise architecture in fulfillment

of the DoD strategic objective is the motivation for this research effort. As previously discussed in 3.0 - Enterprise Architecting, using ilities as a guide in the architecting of could-be architectures and their evaluation to determine the to-be architecture provides a unified approach to ensure the long-term characteristics that are important to the enterprise are incorporated. This requires the definitions of the ilities to be agreed upon by the entire EA team to ensure concurrence of could-be architecture evaluations and to-be architecture selection. As identified by key stakeholder, the critical ilities required to support the T&E enterprise strategic objective of becoming a sustainable enterprise are listed and defined as follows:

- Adaptability – "the ability of a system to change internally to fit changes in its environment [and] may undergo self-modification (e.g., a thermostat controlling the heating of a subsystem)"(Allen & Moses, 2001, p. 4)
- Agility – "ability of a system to be both flexible and undergo change rapidly" (Allen & Moses, 2001, p. 4)
- Robustness – "ability to perform under a variety of circumstances; ability to deliver desired functions in spite of changes in the environment, uses, or internal variations that are either built-in or emergent" (Allen & Moses, 2001, p. 4)

Additional architectural properties were also identified by key stakeholders, which are critical for enterprise's energy infrastructure to facilitate the transition to an adaptable, agile and robust T&E organization. These energy infrastructure architectural properties establish guidance for the development of the could-be architectures and for setting the energy infrastructure requirements of the T&E enterprise, as detailed in 5.1 - Energy Infrastructure Could-Be Architecture. The Ilities Relationship Model, depicted in Figure 10, establishes the hierarchical relationships between the enterprise's strategic objective, the critical enterprise-level properties which would be used as could-be architecture evaluation criteria, and the critical energy infrastructure properties which would be used to develop could-be energy infrastructure architectures. The top tier of the pyramid indentifies the strategic objective of the enterprise which is driving the need for its transformation. For the DoD T&E enterprise, transitioning to a sustainable enterprise is the overarching strategic objective, and in result this is the vision with which the EA team guides the conduct of their enterprise architecting efforts. To reach this vision, the EA team defines the enterprise-level characteristics, or properties, which are critical to transforming the T&E enterprise into a sustainable enterprise.

These enterprise-level properties, as identified by key T&E stakeholders, build the middle tier of the model and are used to guild the architecting and the evaluation of the could-be enterprise architectures. The bottom tier, the foundation of the pyramid, is comprised of the properties which key T&E stakeholders identified as vital for an energy infrastructure which is to enable an adaptable, agile, and robust enterprise. This foundation is to be used by the EA team to drive the architecting and design of the energy infrastructure for the T&E enterprise and will be discussed in 5.1 - Energy Infrastructure Could-Be Architecture.

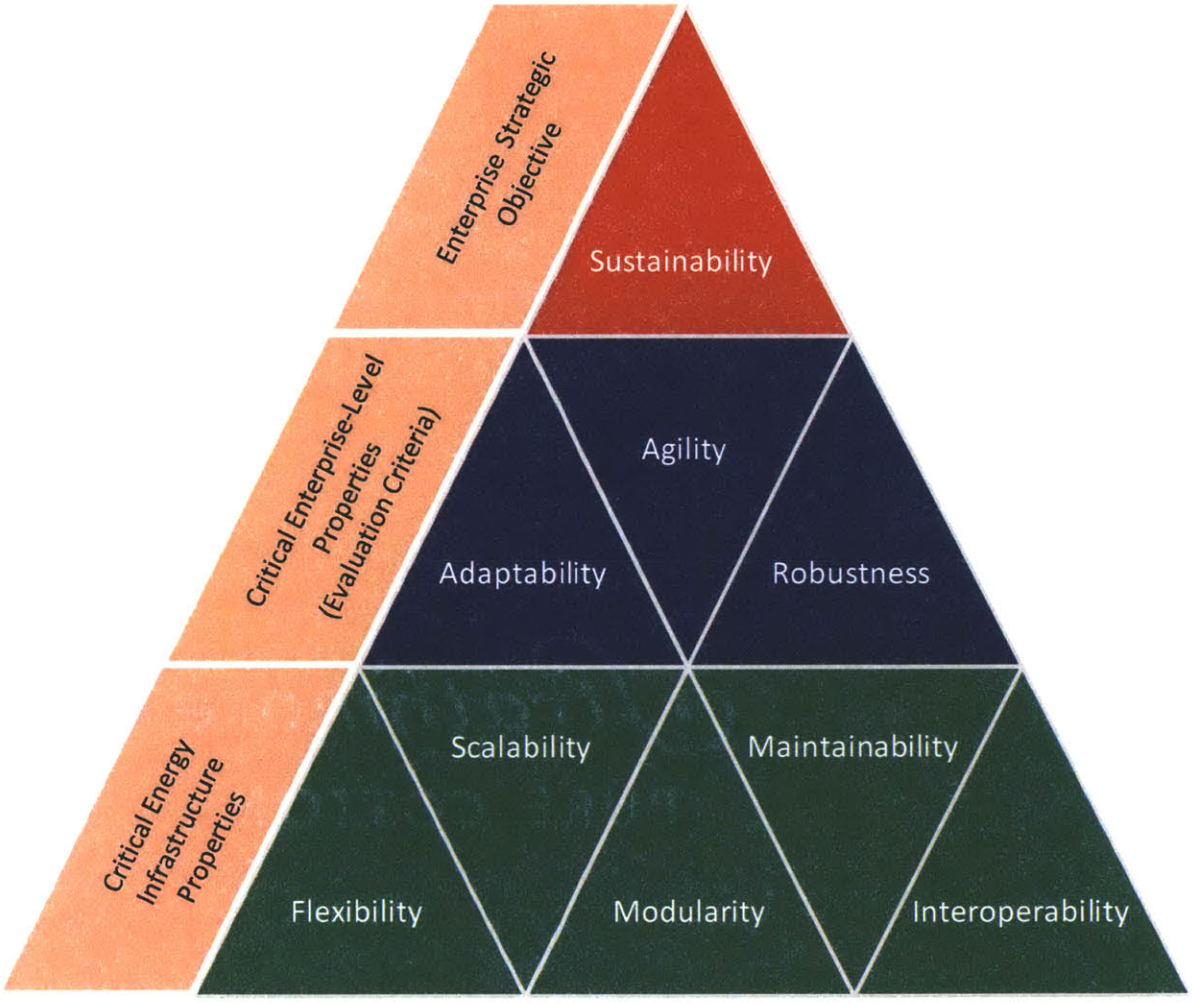

Figure 10: T&E Enterprise Ilities Relationship Model

3.2 – Stakeholder Analysis

As depicted in Figure 11, Nightingale and Srinivasan propose, four steps for conducting an enterprise stakeholder analysis: identification, prioritization, value elicitation, and value exchange analysis.

Figure 11: Stakeholder Analysis Process (Nightingale & Srinivasan, 2011, p. 61)

During the first step, identification, the relevant stakeholder groups and key individual enterprise stakeholders are identified. These stakeholders are then prioritized based on their relative importance to the enterprise in reaching its strategic objectives. To determine each stakeholder group's importance, each group's stakeholder saliency is evaluated. Stakeholder saliency is "the degree to which the enterprise gives priority to different stakeholder needs" (Nightingale & Srinivasan, 2011, p. 67). Saliency is determined by understanding the type of stakeholder and their relationship attributes with the enterprise, as defined in Table 3 and further depicted in Figure 12. Stakeholders who are classified as definitive have higher saliency than those classified as expectant or latent.

Table 3: Description of Stakeholder Types and Relationship Attributes [Derived from (Mitchell, Agle, & Wood, 1997), (Grossi, 2003, pp. 31-32)]

Relationship Attributes	Descriptions
Power	Stakeholder has the ability to "impose" their will on Enterprise
Legitimacy	Existing perception of or assumed right of stakeholder
Urgency	Stake is time-sensitive or stakeholder possesses critical importance to the Enterprise
Stakeholder Types	
Definitive	Possess all three relationship attributes
Expectant	Possess two of three relationship attributes
Latent	Possess only one relationship attribute

Next, value elicitation is performed to determine the enterprise's ability to deliver value to the stakeholders and the importance to the stakeholders of the value being delivered. Finally, the value exchange analysis, the determination of the bi-direction value exchange between the enterprise and its stakeholders, based on importance of the value and how well it is delivered, must be understood (Nightingale & Srinivasan, 2011, pp. 61-78). Any deficiencies in value delivery to definitive stakeholders should be the most important focus of the transformation effort, followed by that of the expectant stakeholders and then latent stakeholders.

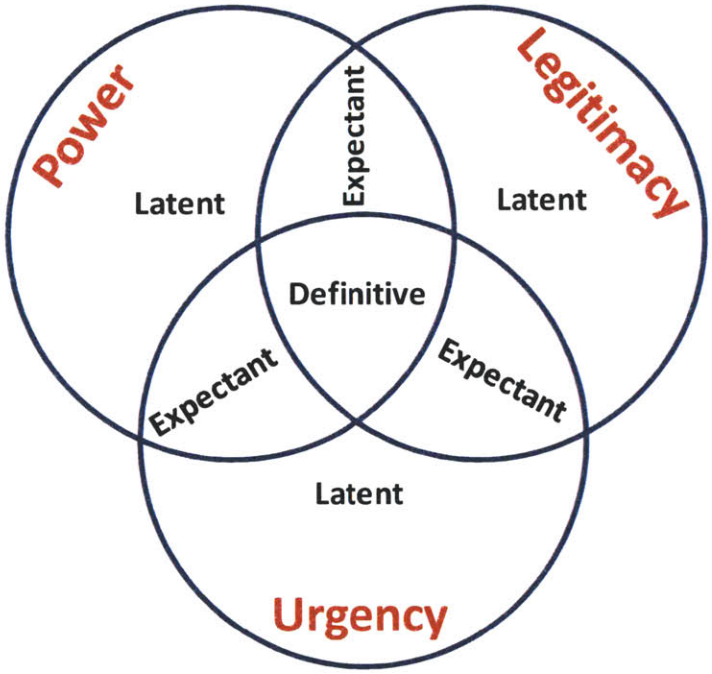

Figure 12: Stakeholder Type and Attribute [Derived from (Mitchell, Agle, & Wood, 1997), (Grossi, 2003, pp. 31-32)]

Chapter 4 – Data Collection: Defining the As-Is Architecture of the DT&E Enterprise

4.0 - A Current DoD T&E Enterprise Architecture

This chapter describes analysis results that are produced by applying EA to define the as-is enterprise and identify its gaps as identified through the enterprise stakeholder analysis. This will be accomplished by first stepping through a clear description of the enterprise being analyzed, including the identification of its key stakeholders and the value delivery performance of the enterprise. The resulting as-is architecture gaps will then be identified. These gaps have been determined by viewing the shortcomings in the value exchange analysis for the key stakeholders through the various EA lenses. Through this analysis and definition process and the resulting research findings the following research question will be answered:

- How can enterprise architecting be used to holistically analyze a DoD T&E enterprise to identify gaps between its current state and its desired state based on its strategic objective, to becoming a sustainable enterprise?

It is essential to define the context in which the enterprise exists. Context, as defined by Nightingale and Rhodes as "the environment in which the enterprise operates including the exogenous influences and uncertainties" (Nightingale & Rhodes, 2011). For this effort, the T&E enterprise will be analyzed at the lowest level of T&E that are known as the Major Range and Test Facility Bases (MRTFBs) within DoD and are, where the DOD performs actual testing and evaluation efforts. Equivalent MRTFBs T&E enterprises include Army White Sands Missile Range (WSMR) in New Mexico, an enterprise within ATEC; the Air Force Flight Test Center at Eglin Air Force Base in Florida, an enterprise within AFOTEC; and the Naval Air Warfare Weapons Division at Point Mugu in California, an enterprise within OPTEVFOR as depicted in Figure 13.

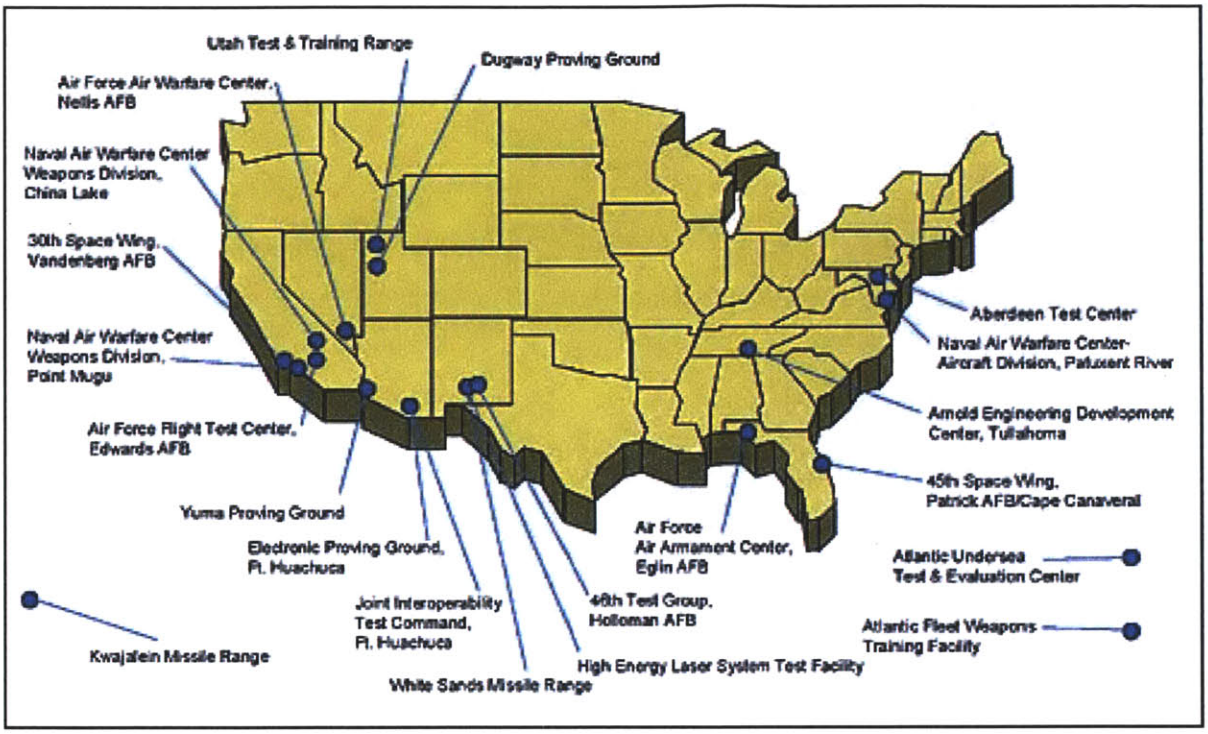

Figure 13: DoD Major Range & Test Facilities Bases (MRTFBs) (Director, Operational Test & Evalution, 1999)

4.1 - T&E Stakeholders and Enterprise Value Delivery

As previously defined, a stakeholder is "any group or individual that can affect or that is affected by the achievement of the enterprise's objectives" (Nightingale & Srinivasan, 2011, p. 2). This includes personnel both internal and external to the organization who either derive value from the enterprise, provide value to the enterprise, or both. The stakeholders for the T&E enterprise are listed and their roles summarized in Table 4, and those with the greatest saliency, the key stakeholders, are identified in the first six rows of the table [Derived from (Cowart, 2011)]. According to Cowart, these are the stakeholders who are most important to the enterprise and whose objectives drive the remaining Enterprise Architecting (EA) effort (Cowart, 2011, pp. 58-60). Grossi devised a water-drop model to describe the relative importance of each stakeholder of an enterprise (Grossi, 2003, pp. 56-58). Figure 14 shows the water-drop model for T&E derived by Cowart (2011), which shows the relative importance of the six key stakeholders by the close coupling in the center drop. This pictorial also brings to light

immediate gaps that exist with the collaboration and coordination between these key stakeholders, specifically the end users and contractors with the four closely integrated T&E stakeholders.

Table 4: DoD T&E Enterprise Stakeholders [Derived from (Cowart, 2011)]

T&E Enterprise Stakeholders	Description
Operational Testers	OT&E (within each branch) personnel responsible for validation of the system through operational assessment to determine operational utility and capabilities
Developmental Testers	DT&E (within each branch) personnel responsible for verification of the system through functional assessment to determine system requirements are met
Program Managers	PM (within each branch) personnel responsible for program execution to cost and schedule and ensure delivery required system performance to requirements
Systems Engineers	SE (within each branch0 personnel responsible for development and integration at the subsystem, system and system of system level ensuring functionality to requirement
Contractors	Contractor personnel responsible for supporting the system development efforts, to include OT&E, DT&E, PM and SE efforts
End User	Warfighter (soldiers, marines, sailors, airmen) personnel inherit the system and is responsible for the operations of the system in wartime and peacetime environments to ensure national security
Acquisition	PEO (within each branch and at DoD level) and Army TRADOC personnel with high level of interest in T&E results to meet acquisition objectives, to include cost, schedule and functionality of system
DoD Level T&E	JITC, TRMC, DDT&E, DOT&E personnel who are responsible for enabling T&E for each branch and across branches through setting of regulation/policy, procedure, funding, oversight, and integration across branches and T&E disciplines
Congress	Congressional personnel who support constituent programs and approve funding for DoD efforts
Taxpayers	Individuals who ultimately fund DoD efforts, vote for congressional candidates who allocate funding, and are the recipients of the national security enabled through our Warfighters
Regulatory Authorities	Primarily government agencies (EPA, FAA, DDTC, etc.) which indirectly impact T&E Enterprise through the creation and enforcement of various regulations

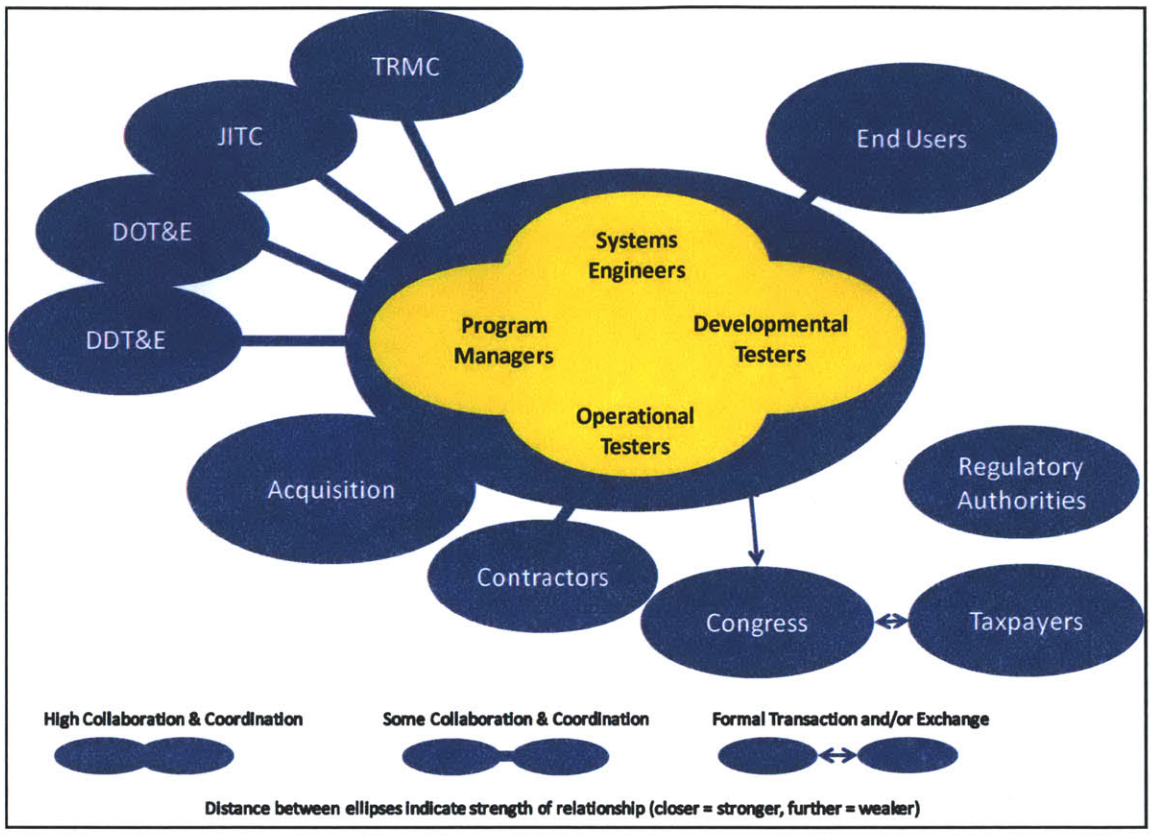

Figure 14: DoD T&E Enterprise Water-Drop Model of Stakeholder Relationships [Derived from (Grossi, 2003)(Cowart, 2011)]

Next, a value exchange analysis was conducted to determine perceived gaps in the value delivery performance of the enterprise from the key stakeholders' perspectives. For T&E, this effort focused on two primary comparisons to determine and value delivery gaps. The first comparison, as depicted in Figure 15, is between the current performance of the enterprise in delivering value to a stakeholder against the relative importance of the stakeholder to the enterprise. This analysis indicates that the operational testers, program managers, and contractor stakeholders' relative importance to the enterprise and the enterprise's value delivery performance resulted in relatively balanced results. The critical value delivery gaps exist between the importance of the developmental testers, systems engineers and end users key stakeholder groups as compared to the performance of the enterprise to deliver value to the stakeholders. Critical gaps are shortcomings in the value delivery performance of the enterprise as perceived by the key enterprise stakeholders.

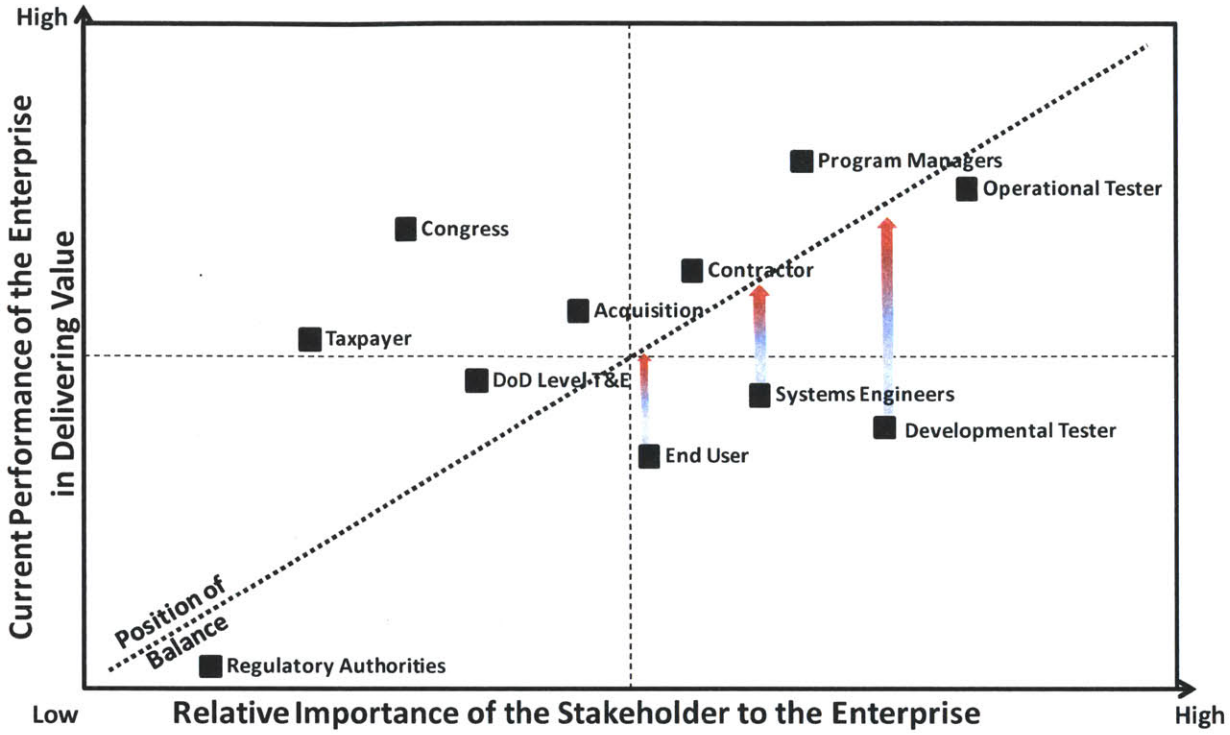

Figure 15: Current-State Value Delivery Performance Verses Importance of the Stakeholders

The second comparison, as depicted in Figure 16, is between the current performance of the enterprise in delivering value to a stakeholder against the relative importance of the value to the stakeholder. The performance of the enterprise in delivering value compares the perception of the key stakeholders within the organization, along with the values provided by the enterprise. These six, as identified in Figure 16, values are a compilation of specific values as identified by each of the key stakeholder groups, the operational testers, developmental testers, program managers, systems engineers, contractors and end users, and also align with the specific roles and responsibilities of the key stakeholder groups. The key stakeholders perceive significant gaps between almost all of the values that are expected to be provided by the organization in the eyes of the key stakeholders. These gaps in value delivery have been identified as the critical gaps that must be corrected for the enterprise in its current state to meet the strategic objectives of the enterprise. To determine where these gaps specifically exist in the as-is architecture, the DoD T&E enterprise must be looked at through the various EA lenses. Nonetheless, a value

exchange analysis can identify significant gaps in delivering value to key stakeholders and in the enterprise's performance in delivering the desired values to its key stakeholders. The two representations of the enterprise value delivery analysis as depicted in Figure 15 and Figure 16, in combination with enterprise water drop model depicted in Figure 14, it becomes clearer that a lack of collaboration and coordination between the key stakeholders is a likely cause for the critical value delivery gaps.

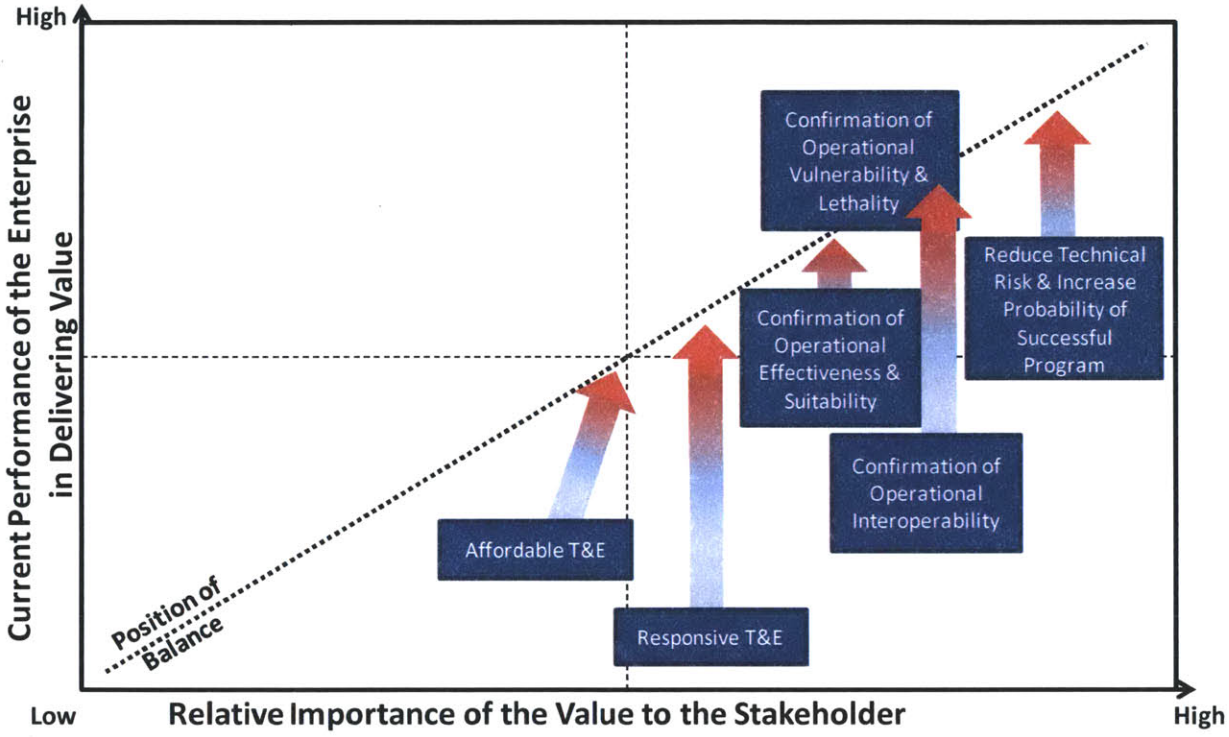

Figure 16: Current-State Value Delivery Performance Verses Importance of the Value

4.2 - EA Views and the Typical T&E As-Is Enterprise Architecture

Prior to walking through each EA view of the DoD T&E enterprise and identifying the gaps, the constraints, strong relational influence between the views and current as-is state of the views should be understood in the context of a typical MRTFB T&E enterprise. Figure 17 is based on the depiction of Nightingales and Rhodes (2009) eight views of an enterprise architecture and presents an overview of the current as-is architecture of a typical MRTFB enterprise.

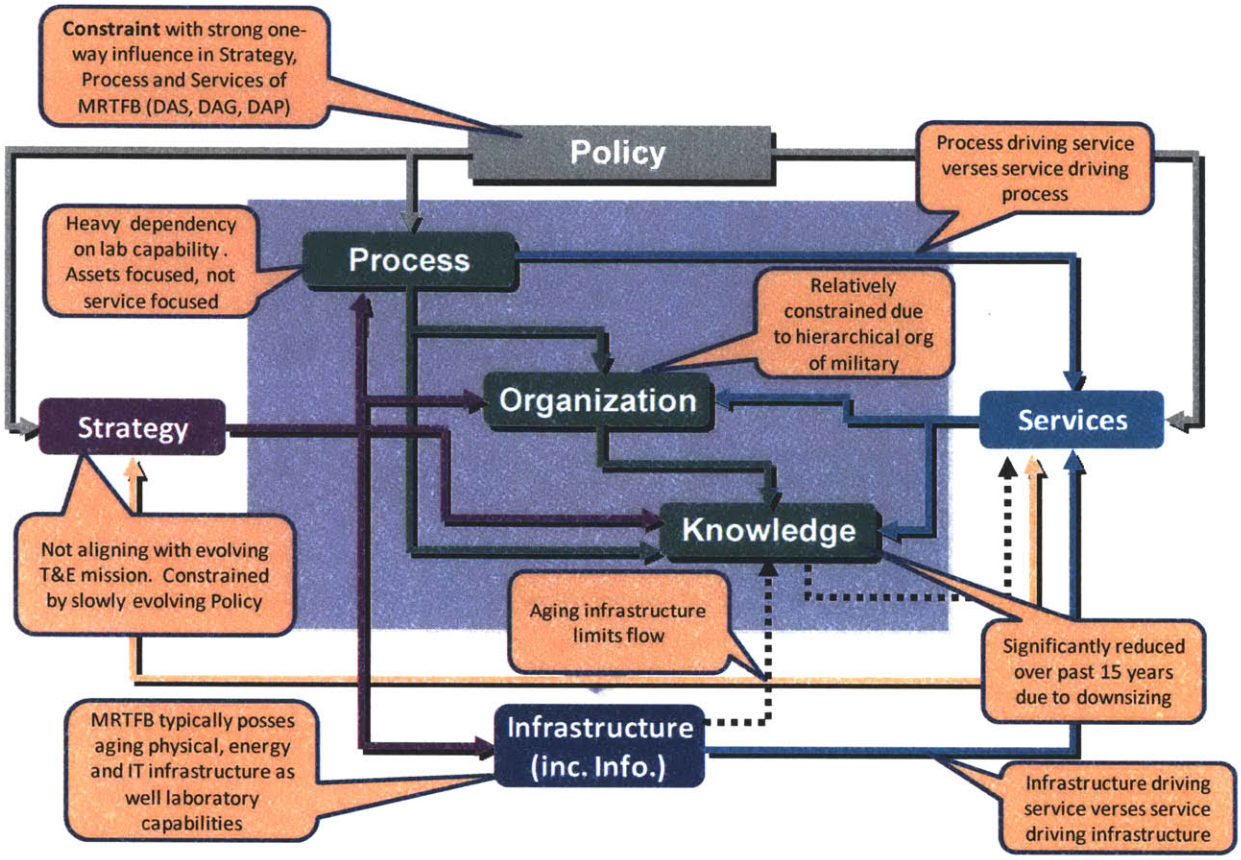

Figure 17: EA Views and Relationships of a Typical MRTFB [Adapted from (Nightingale, 2009, p. 6)]

4.2 - Policy and Strategy Views Gap Identification

The policy view considers the "external regulatory, political and societal environments in which the enterprise operates" and the strategy view examines the "strategic goals, vision and direction of the enterprise including the business model; enterprise metrics and objectives" (Nightingale, 2009). In the context of the MRTFB enterprise, the policies and strategies are highly constrained by the branch-level and OSD-level T&E organizations. Two publications defined the T&E policy and process at the OSD-level: DoD 5000.01, *Defense Acquisition System* (DAS) and DoD 5000.02, *Operations of the Defense Acquisition System*. This direction flows into branch specific directives defined in Table 5.

Table 5: Branch Acquisition and T&E Policy

Branch	Policy	Description
Army	AR73-1	Test and evaluation policy
	DA PAMPHLET 73-1	Test and evaluation in support of systems acquisition
Air Force	AFR 800-2	Acquisition program management
	AF POLICY DIR 99-1	Test and evaluation processes
	AFI 99-103	Capabilities-based test and evaluation
Navy	SECNAVINST 5000.2B	Implementation of mandatory procedures for defense acquisition programs
Marine Corps	USMC ORDER 5000.11B	Test and evaluation of systems and equipment for the marine corps

As directed by WSARA, established in May of 2009, there is more stringent acquisition and T&E oversight policy than previously required for major defense acquisition programs. WSARA also directed the implementation of the DDT&E organization, which was the most recent update which significantly affects OSD-level T&E policy. As of 2011, the results of this effort on the DoD acquisition and T&E communities were still under evaluation to determine their impact and effectiveness. This research effort identified additional changes in policy and strategy based on applying the EA methodology. Since the DoD is extremely hierarchical in nature, the policy and strategy at the highest levels drive execution at the lowest levels. Enterprise changes at the OSD-level could have the most significant impact on the MRTFBs if the changes identified in this research were appropriately funded. However, this level of policy and strategy is an external constraint on the MRTFB enterprise and, accordingly, the policy and strategy views gaps must be addressed at the OSD-level T&E enterprise.

4.3 - Organizational View Gap Identification

The organizational view examines the "organizational structure of the enterprise as well as relationships, culture, behaviors and boundaries between individuals, teams and organizations", as defined by Nightingale (2009). Currently, each MRTFB focuses on testing a

single or a few types of systems, such as missile systems or underwater naval systems. This drives the specific range's capabilities to support the T&E of the class of system under test.; however, this also results in redundant T&E specialties and capabilities across MRTFBs and the branches. As a consequence, duplicate resources, knowledge and supporting test infrastructure are spread across the branches and locations. Development of discrete Centers of Excellence (CoE) would reduce the dispersion of limited resources across locations and branches. Each CoE should focus on common T&E capabilities, such as environmental, underwater, autonomous, etc., and not based on component, platform, sub-system and SoS type T&E, as the current state of organization to which the T&E is devised, For this transformation to occur, a shift in strategy at the OSD-level, specifically initiated by the TRMC as described in Table 1: OSD Level T&E Organizations and Roles & Responsibilities, would have to be devised and flown down through the DoD T&E organization.

If CoEs could be coordinated across the DoD, early assignment to the appropriate MRTFBs would allow earlier coordination of the T&E efforts to allow better alignment as they approach actual T&E events, such as DT&E, IOT&E, LFT&E etc. The MRTFBs also need to be organized to help enable early alignment with T&E efforts that will be required to occur at the MRTFB. Implementation of contractual and system requirements, which would have a strong link with the process view, will enable the appropriate hooks in the system to allow ease of data collection and analysis for T&E events. For example, standardization of data collection interfaces protocols, languages, etc. would reduce complications and time involved with data collection and analysis. Identification and coordination for required T&E assets and testing capabilities, such as specific laboratory test equipment, personnel with specialty training, etc., early in acquisition program effort would increase the responsiveness of the T&E enterprise. Early alignment should produce a more affordable and responsive T&E effort by planning for personnel, test and infrastructure resource allocation early to increase likelihood of availability when required. The enterprise would need to be organized to rapidly set-up, execute and complete T&E efforts, including access to appropriate T&E assets and other systems for SoS T&E and to help enable ease of transition of systems and information critical to their fielding and sustainment to the warfighter.

Organizing in a less hierarchical fashion and more alignment based on system implementation into the T&E process, execution of T&E and transition to the combat units, would help bridge the gap between the Contractor and End User and the other key T&E stakeholders with more coordination and collaboration early in and throughout the T&E effort. As previously discussed, organizing each MRTFB and within each enterprise into multiple CoEs, with specialized personnel skill sets and test assets, would enable capability gaps to be addressed and a consolidation of limited resources. This would require increased involvement in training programs specific to the CoE, which would have strong interrelationship with the knowledge view of the enterprise.

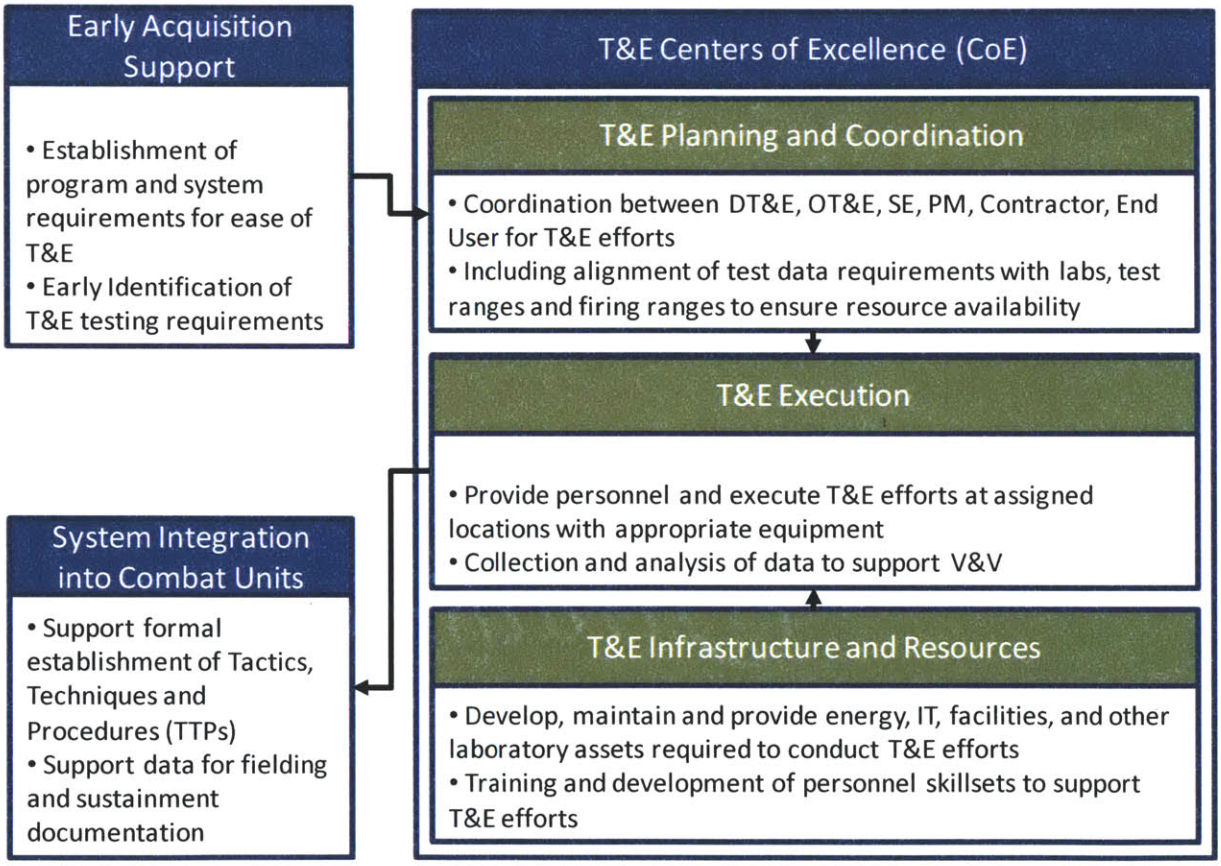

Figure 18: Notional T&E Organizational View

4.4 - Service and Product Views Gap Identification

Since the MRTFBs support the T&E requirements of the DoD acquisition process, their enterprise is primarily service-based and not product-based. For the MRTFB T&E enterprise, the service view, defined as "services(s) delivered and or supplied by the enterprise, including in support of products" in Table 2: Enterprise Architecture View Descriptions (Nightingale, 2009), focuses on the collection and analysis of data to derive the worth of a component, or higher level of the system or SoS, as it relates to the verification and validation of some set of functional and/or performance requirements. A few products are developed, specifically the Test & Evaluation Strategy (TES) and Test & Evaluation Master Plan (TEMP) as depicted in Figure 2: Pictorial View of T&E support to DAP , to support the delivery the enterprise services.

Results from this study have indicated that most MRTFBs are not being viewed as a comprehensive T&E service provider by the DoD acquisition community. This is resulting in the MRTFBs being viewed as a location at which specific testing efforts can be conducted by the system acquisition program's PM and supporting contractors, by leveraging their test infrastructure and support personnel. The primary value of the MRTFBs, as the provider of a T&E service, is being overlooked. A reduction in the number of personnel and other significant resources at the MRTFBs were the result of years of OSD-level policy and strategy changes driven by congressional budgetary cuts since the end of the Cold War era of the early 1990's (Adolph, 2008). Over this same time period, the DAS process required for T&E to support the acquisition program has not changed, which has resulted in the contractors who are developing systems filling in to support the gap in capabilities. What is now considered a norm, to a large extent, is for a contractor who is developing a component or PM who is acquiring the component to verify their own component performance capabilities at the earlier stages of T&E. When contractors conduct self-verification of their system capabilities, the identification of performance shortcomings and technical risks are less likely to be acknowledged as early as possible. This results in delays in the identification of technical shortcomings and risks to the later stages of the acquisition program, at which point corrective actions are very costly and time consuming, resulting in program delays and cost overruns or for capabilities to be removed from the system.

4.5 - Knowledge and Process Views Gap Identification

The knowledge view examines the "implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise" and the process view inspects the "core leadership, lifecycle and enabling processes by which the enterprise creates value for its stakeholders" (Nightingale, 2009, p. 6). These two views are combined as they are closely intertwined in the T&E enterprise under review. Knowledge enables personnel to execute the processes that provide the service of testing and evaluation to the acquisition community. Well trained personnel are a necessity to ensure that T&E efforts are conducted effectively and efficiently. The reduction in the number of T&E personnel, at the MRTFB level, has significantly impacted the ability of the MRTFB to deliver this value. The gap in the quantity of personnel leads to a capabilities gap that has been absorbed by the system acquisition programs PM and contractors, leading to contractors conducting self-verification of their products at earlier stages in the acquisition program. Increasing the number of personnel within the enterprise requires the focus of human resource (HR) efforts to attract, retain, and grow talented personnel. A focused training program is required to equip the personnel with the require knowledge to execute the processes and provide the T&E services. Balanced HR and training programs fulfill enterprise personnel requirements by attracting and retaining knowledgeable individuals. The funding constraints have also led to antiquated T&E infrastructure and test assets at a number of MRTFBs. The combination of a reduction in knowledgeable personnel to conduct T&E at the MRTFBs and the oftentimes decaying T&E infrastructure have led a decline in strong, well-defined T&E processes at a number of MRTFBs. This led to the MRTFB being viewed as a location where T&E infrastructure and support personnel are available to the acquisition community, and not as the key stakeholders of the MRTFB T&E enterprise desire, to be the T&E service provider within the DoD acquisition community.

4.6 - Infrastructure View Gap Identification

As identified by Nightingale, the information view reviews the "information needs of the enterprise, including flows of information as well as the systems and technologies needed to ensure information availability" (Nightingale, 2009, p. 6). For this thesis, the information view has been expanded to include all infrastructures needs of the enterprise. By viewing the MRTFB

T&E enterprise through the infrastructure lens and the energy infrastructure lens, this section and chapter 5 describe analysis results and research findings which answer the following research question:

- How does viewing an enterprise through an infrastructure lens, specifically energy infrastructure, better enable EA to support enterprise transformation to a sustainable enterprise and value delivery to its key stakeholders?

Infrastructure facilitates the execution of the T&E by a DoD T&E enterprise resulting in the T&E service to be provided and the enterprise to provide value to its stakeholders. Infrastructure includes facilities, land, laboratory and physical testing assets, energy infrastructure, IT networks, and frequency spectrum. As identified by Myers (2009), when analyzing the gaps in the infrastructure, one must

1. review if there is the right infrastructure to support current and future testing requirements
2. determine if there is a sufficient capacity to support the MRTFB T&E efforts.

For a specific MRTFB to perform the review and make the determination they must have clear understanding of the current and future T&E efforts and their infrastructure requirements for successful completion of the testing. Typically, there is good understanding of the current T&E requirements, but the preparations for future testing requirements for often unknown systems with new capabilities, such as autonomous systems, can make this effort difficult. Funding reductions, imposed by the congressional budget cuts after the conclusion of the Cold War, only intensify infrastructure limitations that result in aging infrastructure which requires increased maintenance costs prolong its operational capability. Additionally, this thesis has identified that large-scale, fixed infrastructure is not well suited to adapt to the T&E required to support testing of emerging systems and their capabilities. A core infrastructure component that enables all T&E to occur is energy infrastructure. The energy infrastructure is the foundation that provides the ability for physical testing through the use of instrumentation, test facilities and ranges, communication networks, and IT systems. The energy infrastructure powers the operations of these assets to enable the collection, flow of, storage, management and analysis of data. The energy infrastructure will be reviewed in more detail in 5.0 - DoD Energy Mandate

and Goal Overview, to solidify the importance of the infrastructure as a view for enterprise architecting and for enabling sustainable T&E at an MRTFB. Ongoing energy initiatives within DoD have arisen since 9/11, which are due largely to the logistical challenges for fuel delivery in Afghanistan and from the rising concerns of reliance on foreign sources of fossil fuels. As described in Chapter 5, these initiatives provide a potential leverage point to use the energy infrastructure to create some initial interest and investment in aligning the MRTFB enterprise to becoming a more sustainable enterprise.

Chapter 5 - Employing a Energy Infrastructure Architecture in support of a Sustainable T&E Enterprise

5.0 - DoD Energy Mandate and Goal Overview

Following the 9/11 terrorists attacks on the United States, energy security rose in priority with the DoD based on the logistical challenges and implications of delivering fuel to remote, operational locations throughout Afghanistan and due to rising concerns of the heavy reliance on foreign oil. Early focuses on energy security were voiced through the *National Security Strategy of the United States of America* where it was stated that energy is vital to "expand economic liberty and prosperity" and that the United States must "accelerate deployment of clean technologies to enhance energy security, reduce poverty, and reduce pollution" (Bush, 2006). This clear direction continued to spread through the release of ODS-level and branch-level energy directives and strategies to reduce reliance on fossil fuels and explore and incorporate alternative energy technologies to support the energy demands of the U.S. armed forces. The intent of these energy initiatives is to lead to a more sustainable fighting force by reducing vulnerabilities inherent in our current energy needs without reducing the lethality of our forces.

The energy initiatives within the DoD could be leveraged by a MRTFB T&E enterprise to gain momentum towards enabling integrated T&E sustainability. By initiating an evaluation of its current practices and devising a strategy to meet the DoD energy mandates a larger realignment can be conducted to align its transformation to its larger enterprise strategic objectives. Since energy is an enabler for almost all efforts within a technology-driven world, a redefining of the how energy is to be generated, stored, managed, and distributed will ripple into enterprise value streams. From powering lighting and computers to complex telemetry and communications equipment, energy infrastructure is a core necessity to power electronic and mechanical devices which are relied upon in the conduct of T&E efforts. Through the application of EA, the interrelations between the energy infrastructure and the other views, such as processes, services, and knowledge, and the other supporting infrastructure components, such as facilities, land, laboratory and testing assets, communication networks, and IT networks, can be more easily understood and exploited to develop momentum to implement enterprise transformation. The establishment of critical energy infrastructure properties, as depicted in

Figure 10, can be used to influence a more adaptable, agile, and robust T&E enterprise architecture.

5.1 - Energy Infrastructure Could-Be Architecture

By focusing on the changing nature of energy infrastructure and the inherent challenges that arise as energy availability becomes scarcer, it becomes evident that a more sustainable energy infrastructure can to lead to a MRTFB T&E enterprises being able to deliver more value using fewer resources. The notion of "test like we fight" requires an agile and mobile T&E methodology to facilitate testing in austere locations while not impacting the test data results. A could-be energy infrastructure should be conceived with these energy-related concepts in mind. However, one must understand that the technologies which are available in today's era will likely become obsolescent in subsequent eras, and the testing requirements of today's era will likely vary from those of subsequent eras. As proposed by Ross and Rhodes (2009), epoch-based thinking is used to "generate and consider a large number of possible future contexts and needs facing a system, along with short term and long term strategies for maintaining a successful system across epochs. An epoch is a "time period with a fixed context and needs; characterized by static constraints, concepts, available technologies, and articulated expectations" (Ross & Rhodes, 2009, p. 23). Applying epoch-based thinking to the development of a could-be energy infrastructure architecture requires the identification and definition of the long-term characteristics which are important to the enterprise, the ilities, as defined previously in 3.0 - Enterprise Architecting.

Specific energy infrastructure architectural properties should be used to guide the architecting and design process. It is difficult to define a generic energy infrastructure architecture that meets the needs of all MRTFB T&E enterprises. However, it is important to develop an architecture that is adaptable, agile, and robust as defined in the key ilities to meet the enterprise strategic objectives of evolving into a sustainable T&E enterprise. Table 6 lists and describes the critical energy infrastructure architectural properties that are important to guiding the development of an energy infrastructure for any MRTFB T&E enterprise. This table expands upon the critical energy infrastructure properties, as defined by the key T&E stakeholders in Figure 10, to provide a guideline in a specific MRTFB T&E energy infrastructure architecture.

The Description column of the table explain how each property should be viewed and used to facilitate the architecting and design of the energy infrastructure of a DoD T&E enterprise. The Enterprise Impacts column of the table describes the enterprise-level impact which would result from the incorporation of the energy infrastructure property. This table should be used to guide in the development of the infrastructure architecture for a MRTFB enterprise with the strategic objective to become a sustainable T&E enterprise.

Table 6: Energy Infrastructure Architectural Properties

Architecture Properties	Description	Enterprise Impacts
Flexibility	Mission specific priorities exist for use by individual departments and agencies within and across T&E enterprises, which may not be in the stated goals and objectives. It is critical to understand these and take a holistic approach, instead of designing the architecture for a specific mission. Interagency cooperation is required.	Supports tailoring the energy infrastructure architecture to multiple missions and scenarios. Promotes sustainability, adaptability and agility.
Scalability	Understand primary scaling strategy to cross epochs – to scale up and down. Modernization of aging infrastructure should be integral to architecture and implementation plans.	Provides the ability to grow and shrink the infrastructure easily and avoids saturation. Promotes sustainability, adaptability and agility.
Modularity	Right sizing the components of the infrastructure based on goals and objectives of various mission is critical. Deployable, transportable containerized power systems, rather than using brick and mortar approach.	Allows the infrastructure to be rapidly deployed based on the evolving demand. Promotes adaptability and agility.
Maintainability	Need to use automatic recovery and provide redundancy to sustain mission critical operations at all times. Instrumentation and software shouldn't be excluded – captures test data, inventory, monitoring & control for the energy infrastructure.	Assures minimal down time for critical energy infrastructure components. Easy to upgrade the components. Supports continuous evaluation and evolution of the energy infrastructure. Promotes sustainability and robustness.
Interoperability	Understanding what systems will need interoperability immediately and standardization of interfaces for future system interconnections. Need to use loose coupling of systems and components. Design the architecture to be as component agnostic as possible.	It is generally ignored characteristic from an efficiency standpoint, but it is paramount when ensuring reliability, promoting reusability, and ensuring scalability of energy infrastructure. Promotes sustainability, adaptability, agility, and robustness.

Chapter 6 - Conclusion and Future Research

6.0 - Conclusions

The question of how Enterprise Architecting (EA) can be used to holistically analyze a DoD T&E enterprise was addressed in this research effort. To support enterprise transformation and improve value delivery to its key stakeholders, EA should be used to identify gaps between its current state and its strategic objectives and view an enterprise through an infrastructure lens, specifically energy infrastructure. This research effort investigated how EA could enable integrated T&E sustainability to meet the evolving DoD landscape. Current DoD financial limitations and MRTFB infrastructure and personnel challenges constrain the ability of the DoD T&E enterprise to ensure continuous adjustment of T&E efforts to rapidly align with the T&E requirements of DoD acquisition process. An EA approach was applied to define the current state of the enterprise, the as-is architecture, and to identify critical gaps to reaching the enterprise's strategic objective as defined by the key stakeholders. Through interviews and research of publically available documentation and reports the strategic objectives of the T&E enterprise was defined: to become an adaptive, integrate T&E enterprise to the meet the evolving DoD landscape.

In chapter 4, section 4.2 - EA Views and the Typical T&E As-Is Enterprise Architecture, the MRTFB T&E enterprise analysis results were used to define the current state of the enterprise and to identify gaps in which are limiting their ability to reach their strategic objectives. Answering the first research question, these results depict how the holistic engineering systems approach of EA, which strongly leveraging the key stakeholders' perceptions, can better identify gaps and interrelations within the enterprise. Potential gaps between the enterprise and its strategic objectives, specifically in a typical DoD T&E enterprise, were identified as they relate to the enterprise value delivery to its key stakeholders. The EA approach used various lenses to analyzing an enterprise through the identification of interrelations between the various facets of an enterprise.

In chapter 5, the Infrastructure view was explored as a candidate view to enable a deeper insight into an enterprise's as-is architecture and the current gaps which limit their ability to reach their strategic objective. Infrastructure was identified as an enabler that allows the

organization to execute their processes and delivery the resulting value to their stakeholders. Infrastructure includes facilities, land, laboratory and physical testing assets, energy infrastructure, and IT networks. Answering the second research question, these results indicate that an infrastructure view has strong interrelations with the other EA views and depicts the infrastructure as an enabler for the enterprise to apply its knowledge through the organization to execute processes and deliver value to its stakeholders. Viewing the enterprise through a information lens alone, would result in a gap in understanding of the interrelations between the physical infrastructure assets so critical to an enterprise's operations. Additionally, the energy infrastructure was identified as a core infrastructure component and the foundation that provides the ability for physical testing through the use of instrumentation, test facilities and ranges, communication networks, and IT systems. The energy infrastructure powers the operations of these assets to enable the collection, flow of, storage, management and analysis of data. The energy infrastructure was specifically investigated and was determined as a critical enabler to allow for a sustainable, integrated T&E enterprise. Additionally, by viewing the enterprise through the infrastructure lens, this thesis has identified that large-scale, fixed infrastructure is not well suited to adapt to the T&E required to support testing of emerging systems and their capabilities.

6.1 - Next Steps and Future Research Considerations

This research was conducted without the establishment of a formal EA team from a MRTFB T&E enterprise and was limited interviews, site visits and a heavily reliance on publically available documentation on the DoD T&E organization. A formal team, comprised of key stakeholders, should be established for a specific MRTFB enterprise to execute a thorough EA effort. This will further validate this research and enable actionable results to be developed in the form of an enterprise transformation strategy. The basic principles and analysis provide in this research effort would provide a guide for the application of EA to a T&E enterprise.

Additionally, as depicted in Table 1: OSD Level T&E Organizations and Roles & Responsibilities, the OSD-level T&E enterprise is comprised of multiple offices which are required to coordinate and collaborate to define the DoD's policy and strategy for each branch. There is a lot of duplication at this level which could certainly be streamlined with the proper

OSD-level T&E architecting. The conduct of an EA analysis at this level would lead to greater results due to the hierarchical structure of the DoD T&E organization. This would identify and define the enterprise's present architecture, such as test infrastructure, organization, and knowledge, which could lead to the reduction in unnecessary redundancies across the branches while making scares resources and capabilities more accessible. The effectiveness and efficiencies across all branches could be coordinated to meet the strategic objectives of the DoD T&E enterprise whole resulting in a more sustainable enterprise.

The could-be energy infrastructure architecture proposed could be used by a MRTFB, or across the DoD T&E enterprise, to leverage the current DoD energy initiatives. If applied with the appropriate test assets (e.g. communication and telemetry equipment, sensors etc.), the proposed energy could-be concept would enable adaptable, agile, and robust T&E to support both fixed and mobile testing efforts. This would require tailoring of the proposed could-be energy infrastructure architecture as proposed in chapter 5 and additional detailing to any critical design requirements specific to the enterprise. As described in 3.1 - Research Approach to Defining the T&E Enterprise, the ilities are vital enterprise properties which can be used to define the long term characteristics which are important to the enterprise, and they "specify the degree to which [enterprises] are able to maintain or even improve function in the presence of change" (McManus, Richards, Ross, & Hastings, 2007, p. 2). The following ilities were identified as the top three priorities, based on key stakeholder feedback, to meet the enterprise's strategic objective to becoming a sustainable enterprise. However the definitions should be further tailored by a formal EA team to align with the specific MRTFB T&E enterprise.

- Adaptability – "the ability of a system to change internally to fit changes in its environment [and] may undergo self-modification (e.g., a thermostat controlling the heating of a subsystem)"(Allen & Moses, 2001, p. 4)
- Agility – "ability of a system to be both flexible and undergo change rapidly" (Allen & Moses, 2001, p. 4)
- Robustness – "ability to perform under a variety of circumstances; ability to deliver desired functions in spite of changes in the environment, uses, or internal variations that are either built-in or emergent" (Allen & Moses, 2001, p. 4)

Finally, in a global environment where the creation of a sustainable enterprise is even more critical than ever, the DoD acquisition and T&E enterprise should be analyzed to determine how to transform into a sustainable enterprise. At this top level within DoD, the most holistic insights would be realized and an enterprise transformation would be able to provide the most impact through the convergence of policy and strategy to align the complete DoD T&E enterprise to meet its strategic objectives.

Future research considerations should include a more in-depth understanding of complexity of enterprise stakeholder interrelationships. The stakeholder model shown Figure 3 does not fully depict the intricacy involved with the relationship between stakeholders. A star model is too simplistic to account for the interrelations which exist both within and outside the boundary of the enterprise. External relationships, and their individual value streams, could have significant harmful impacts on the enterprise if they reside within or are adjacent to the market area of the enterprise. If not understood and accounted for, these value streams could lead to competing priorities for a stakeholder or even missed opportunities for the enterprise. Missed opportunities can negatively impact an enterprise as they allow competition to usurp the enterprise's market or even their products. This linkage between stakeholders, both formal and informal, should be explored to determine how various stakeholder networks can either enable or restrain an enterprise's ability to continue to deliver value and meet their strategic objectives.

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Acronym List

AFOTEC – Air Force Operational Test and Evaluation Center

ASC – Armed Services Committee

ATEC – Army Test and Evaluation Center

CoE – Center of Excellence

COTS – Commercial-off-the-Shelf

DAG – Defense Acquisition Guide

DAS – Defense Acquisition System

DAU – Defense Acquisition University

DDT&E – Director, Developmental Test and Evaluation

DoD – Department of Defense

DOT&E – Director, Operational Test and Evaluation

DT&E – Developmental Test and Evaluation

DTM – Directive Type Memorandum

EA – Enterprise Architecting

EPA – Environmental Protection Agency

EOA – Early Operational Assessment

FAA – Federal Aviation Administration

FOC – Full Operational Capability

FOT&E – Follow-on Operational Test and Evaluation

IT – Information Technology

IOC – Initial Operational Capacity

IOT&E – Initial Operational Test and Evaluation

JITC – Joint Interoperability Test Command

LFT&E – Live-Fire Test and Evaluation

MCOTEA – Marine Corps Operational Test and Evaluation Activity

MDAP – Major Defense Acquisition Program

MRTFB – Major Range and Test Facility Base

O&M – Operational and Maintenance

OA – Operational Assessment

OPTEVFOR – Naval Operational Test and Evaluation Force

OSD – Office of the Secretary of Defense

OT&E – Operational Test and Evaluation

PM – Program Management

PQT – Product Qualification Test

SE – Systems Engineering

SoS – System of Systems

T&E – Test and Evaluation

TEMP – Test and Evaluation Management Plan

TEO – Test and Evaluation Office

TES – Test and Evaluation Strategy

TOC – Total Ownership Costs

TRADOC – U.S. Army Training and Doctrine Command

TRMC – Test Resource Management Center

TTPs – Tactics, Techniques, and Procedures

V&V – Verification and Validation

WSARA – Weapons Systems Acquisition Reform Act

WSMR – White Sands Missile Range

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