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Tactical Edge Characterization Framework

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Executive Summary

Many approaches commonly used to develop a Service-Oriented Environment (SOE) presume the availability of reliable, consistently available networks that provide significant bandwidth and little to no latency. Since this is often not the case across the Department of Defense's (DoD) networks, the current development methods might not provide reliable capability to users in a Tactical Edge (TE) environment.[1] This Enterprise Systems Engineering (ESE) Capstone activity aims to ensure the viability of a SOE to a broader domain of tactical users by gaining a better understanding of the TE and quantifying its characteristics.

During Fiscal Year (FY) 2007, the ESE Capstone activity developed a Tactical Edge Framework (TEF). The primary objectives of the TEF are 1) to provide a classification of disadvantaged users (i.e., users operating in a TE environment), and 2) to provide a common vocabulary to characterize TE environments. The common vocabulary allows the TE characteristics to be quantified and solutions to be identified to explicitly address the quantified characteristics. As the DoD's components deliver services to the TE, the TEF's common vocabulary and use of consistent solutions will promote interoperability across component-specific implementations. The TEF was documented in two papers; "Common Vocabulary for Tactical Environments", which defines a common vocabulary that identifies classes of disadvantaged users at the TE and characterizes their environments as a set of constraints [2], and "Design Patterns for Tactical Environments,", which describes a set of repeatable solutions (i.e., design patterns) to mitigate the common TE constraints [3].

The focus of the FY 2008 activity was to socialize the TEF and facilitate its transition to the DoD. The socialization of the TEF across the DoD's components and the component's commands resulted in the validation and evolution of the TEF. The TEF's evolution included incorporating Central Command's (CENTCOM) characterization of the tactical edge into the TEF, as described by the "Disadvantaged User" white paper, and tailoring the TEF to better incorporate the DoD's component-specific perspectives of the TE. Furthermore, the common vocabulary from the TEF was aligned with authoritative definitions of terms from joint publications based on work completed by the Core Enterprise Services to the Tactical Edge (CESTE) Focus Group.

Another focus of the FY 2008 activity was to apply the TEF across multiple DoD programs to demonstrate its value. The TEF was applied throughout the service acquisition lifecycle, from the collection of users' requirements, to documenting use cases, to the design and development of a service. TEF's applicability was also demonstrated in managing the portfolio of services at the TE. The TEF was employed by:

- Special Operations Command's (SOCOM) Tactical Local Area Network in interviewing users at Tactical Special Operations Centers to collect functional requirements and usage patterns.

[1] Tactical edge is defined by Defense Information Systems Agency (DISA) as anything beyond the Defense Information Systems Network Point-of-Presence.

- Net-Enabled Command Capability (NECC) program office to characterize Disconnected, Intermittent, and Limited environments.
- CESTE Focus Group to develop Performance and Service Reference Models and departmental guidance for delivering Core Enterprise Services into and throughout the TE.
- Net-Centric Enterprise Solutions for Interoperability (NESI) to define characteristics of TEF classes of environments' such that relevant and tailored NESI guidance and best practices can be identified for each class of TE environment.

As we reflect on the lessons learned from the ESE Capstone activity and consider future setups to support the realization of services to the TE, we believe that use of the TEF should be further institutionalized at a departmental level. In support of this, we recommend the following:

- Joint Staff and doctrinal leads from the components should adopt the TEF to establish DoD-wide definitions for the classes of TE environments and use the TEF's common vocabulary to characterize them.
- The DoD Chief Information Officer and the Net-Centric (NC), Command and Control, and Battlespace Awareness Capability Portfolio Managers should employ the TEF to define Service and Performance Reference Models in order to establish an NC Enterprise Architecture.
- Defense Information Systems Agency's Net-Centric Enterprise Services and NECC, in conjunction with the DoD's component-specific Programs of Record developing enterprise services (e.g., Consolidated Afloat Networks and Enterprise Services, Army System-Of-Systems Common Operating Environment, Marine Corps Enterprise Information Technology Services, and Air Force's Air and Space Operations Center as a Weapon System) should use the TEF to define and document interfaces and design patterns to achieve federation and meet Quality of Service requirements across DoD component-specific TE platforms.

The adoption of a common characterization of the TE and the use of consistent design patterns will minimize the architectural differences across the DoD's components and promote interoperability across component-specific service implementations at the TE.

Acknowledgements

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- Jeffrey Higginson and Marwan Sabbouh for providing valuable input as consultants throughout the project.
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- David Edwards for his collaboration in harmonizing the TEF with Central Command's "Disadvantaged User" white paper (working with Kris Newport and Robert Lee), socializing the TEF within the Special Operations Command community, and using the TEF as part of the Tactical Local Area Network program.
- Bradford Mercer and Kenneth Griesi for their collaboration in providing the Navy's input to evolve the TEF and using the TEF within the Consolidated Afloat Networks and Enterprise Services program.
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- David Miller and Janet Manu for their collaboration in socializing the TEF with the Core Enterprise Services to the Tactical Edge Focus Group.
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1. Introduction

Many approaches commonly used to develop Service-Oriented Environments (SOE) presume the availability of reliable, consistently available networks that provide significant bandwidth and little to no latency. Since this is often not the case across the Department of Defense's (DoD) networks, current development methods might not provide reliable capabilities to users in a Tactical Edge (TE) environment[2]. This Enterprise Systems Engineering (ESE) Capstone activity aims to ensure the viability of an SOE to a broader domain of tactical users by gaining a better understanding of the TE and quantifying its characteristics.

During Fiscal Year (FY) 2007, the ESE Capstone activity developed a Tactical Edge Framework (TEF). The primary objectives of the TEF are to 1) provide a classification of disadvantaged users (i.e., users operating in a TE environment) and 2) to provide a common vocabulary to characterize TE environments. The common vocabulary allows the TE characteristics to be quantified and subsequently, solutions to be identified to explicitly address the constraints. As the DoD's components deliver services to the TE, the TEF's common vocabulary and use of consistent solutions (i.e., design patterns) will promote interoperability across component-specific implementations.

The results of this work are documented in two papers; "Common Vocabulary for Tactical Environments," which defines a common vocabulary that identifies classes of disadvantaged users at the TE and characterizes their environments as a set of constraints [2], and "Design Patterns for Tactical Environments," which describes a set of repeatable solutions (i.e., design patterns) for the commonly occurring problems [3]. These design patterns define options to help mitigate the constraints at the TE and enable the delivery of services to users in constrained environments. The paper also documents infrastructure requirements and a reference implementation associated with the design patterns.

The focus of the FY 2008 activity was to apply the TEF to DoD programs, while continuing to socialize and evolve the TEF and facilitate its transition to the DoD. The activity's three major thrusts were to:

- Socialize the TEF across the DoD's components and the components' commands.
- Evolve the TEF, harmonize it with other representations of the TE, and validate it with the DoD's components.
- Apply the TEF to tactical Programs of Record (PoR) across the DoD to demonstrate its value throughout the service acquisition lifecycle, including collecting users' requirements, documenting use cases, designing and developing services, and managing a portfolio of services at the TE.

This paper is organized as follows: Section 2 of this paper provides an overview of the components of the TEF, including the common vocabulary and classes of TE environments. Section 3 describes how the TEF evolved in FY 2008, including the tailored versions developed

[2] Tactical Edge is defined by DISA as anything beyond the Defense Information Systems Network's (DISN) Point-of Presence (PoP).

for the Navy, Army, and Special Operation Forces. Section 4 details how the TEF was applied to provide guidance for the DoD's programs by using the TEF to support the collection of users' requirements and use case documentation, the design and development of a service, and management of a portfolio of services at the TE. Section 5 provides an overview of the TEF website. Section 6 provides a summary of accomplishments and recommendations for advancing the delivery of services to the TE.

2. The Tactical Edge Framework

The TEF provides a common vocabulary for identifying constraints at the TE. Employing these common terms allows one to recognize commonalities across the Services' TE platforms. The FY 2007 work created the common vocabulary and identified a set of design patterns; the FY 2008 work used the vocabulary and design patterns as the first essential step in applying the TEF to provide guidance across the DoD's programs.

2.1 Common Vocabulary

The common vocabulary is a fundamental part of the TEF; it provides the building blocks for a user to characterize the TE environment. The common vocabulary consists of a set of attributes and possible values for the attributes. The attributes represent the constraints of the environment that are important to consider for the delivery of services to the TE. The TEF attributes characterize the network, system, physical environment, operational and security constraints. (See Figure 1.)

Network	**Operational**	**System**
• Connectivity • Bandwidth • Latency • Reliability • Predictability	• Repairability • Decision Timelines • Content • System Training	• System Processing • Storage • Standard User Interface • Ruggedness • Size, Weight, & Power (SWaP)
Physical Environment	**Security**	
• Heating, Ventilation, and Air Conditioning (HV/AC) • Lighting • Hazards	• Confidentiality • Integrity • Availability	

Figure 1. Common Vocabulary for TE Environments

The common vocabulary can be used to describe the TE constraints. (See Figure 2.) Red, yellow, and green indicate the degree to which a particular value is a constraint; green represents minimal to no constraints, yellow represents moderate constraints, and red represents severe

constraints. The end result is a consistent characterization that can be used to compare constraints across the Services' TE platforms.

Figure 2. Using the Common Vocabulary to Characterize a Destroyer

The common vocabulary of the TEF that was developed during the FY 2007 ESE Capstone activity was applied and verified during the FY 2008 ESE Capstone activity. In addition, during FY 2008, the vocabulary was aligned with authoritative definitions of terms from joint publications based on work completed by the Core Enterprise Services to the Tactical Edge (CES2TE) Focus Group. The vocabulary is provided in Figure 1 and the authoritative definitions are provided in Appendix B. All definitions are from Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms. As amended through May 30, 2008 (http://www.dtic.mil/doctrine/jel/doddict).

In addition to aligning the vocabulary with authoritative definitions from Joint Publication 1-02, the vocabulary can also be cross referenced with existing terms of reference, such as "Tactical Edge Gateways Functional Taxonomy," in Appendix C [1].

2.2 Classes of Tactical Edge Environments

Characterizing platforms using the TEF's common vocabulary can help classify platforms that have similar constraints. When constraints are similar, rather than treating each platform individually, it is useful to define a representative set of classes in which to bin the platforms. (See Figure 3.) The classes of TE environments defined in the TEF provide the benefit of reducing the classification of TE platforms to a manageable set, which leads to reusable solutions across multiple platforms and DoD components. The classes of TE environments defined in the TEF are based on the analysis of use cases across the DoD to identify commonalities in the constraints of the TE environment. The class names and attribute values may be tailored to suit specific DoD components' terms of reference and constraints.

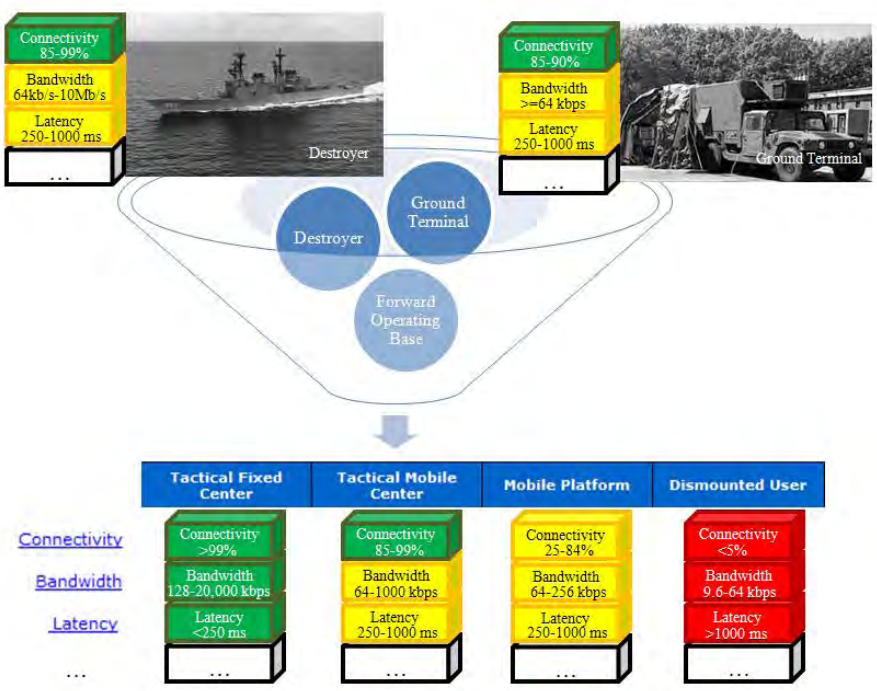

Figure 3. Binning Platforms With Similar Constraints Into a Representative Class

3. Evolution of the Tactical Edge Framework

In FY 2008, one of the major thrusts was the evolution of the TEF. This evolution was the result of two primary activities: 1) harmonizing the TEF with the CENTCOM's TE representation, and 2) tailoring the TEF's attribute values for particular DoD components.

3.1 Harmonizing With the Central Command Representation

The TEF was harmonized with findings from another effort described in the "Disadvantaged User"[3] white paper. The names of the classes of TE environments, the common vocabulary, and specific values were harmonized. Some key decisions that came from this harmonization process are documented in Appendix A.

The results of the harmonization process are reflected in the TEF. The numerical values in the TEF are a result of combining the TEF's values with CENTCOM's values as defined in the "Disadvantaged User" white paper and then further iterating with Subject Matter Experts (SMEs) as described in Section 3.2. The TEF that resulted from this FY 2008 harmonization activity is shown in Figure 4. The rows represent the common vocabulary used to describe the constraints at the TE. Each column represents a unique class of TE environment. The colors define the

[3] http://communityshare.mitre.org/sites/g051/CENTCOM/Products/Forms/AllItems.aspx

degree of constraints; green represents minimal to no constraints, yellow represents moderate constraints, and red represents severe constraints.

		Tactical Fixed Center	Tactical Mobile Center	Mobile Platform	Dismounted User
LAN Network	Connectivity	>85%	>85%	25-84%	5-24%
	Latency	<250 ms	<250 ms	>250ms	>250 ms
	Bandwidth	128 kbps-100 Mbps	128 kbps-100 Mbps	1-128kbps	1-128 kbps
	Reliability	>90%	>90%	>90%	>90%
	Predictability	predictable	mostly predictable	less predictable	unpredictable
WAN Network	Connectivity	>99%	85-99%	25-84%	<5%
	Latency	<250 ms	250-1000ms	250-1000ms	>1000ms
	Bandwidth	<20 Mbps	128-1 Mbps	128-256 kbps	9.6-64 kbps
	Reliability	>90%	>75%	<75%	<75%
	Predictability	predictable	predictable	less predictable	less predictable
System	Standard User Interface	desktop – laptop	desktop - laptop	laptop - tablet - handheld	laptop - tablet - handheld
	Processing	servers – workstations	servers - workstations	single workstations - handhelds	single workstations - handhelds
	Storage	large data storage devices	large data storage devices	single hard drives	single hard drives
	Ruggedness	few ruggedness considerations	few ruggedness considerations	many ruggedness considerations	many ruggedness considerations
	Size	> 10 sq ft	> 10 sq ft	< 10 sq ft	< 3 sq ft
	Weight	100s lbs	100s lbs	10 - 100 lbs	< 10 lbs
	Power	grid, macro generator	generator - batteries	generator - batteries	batteries
Environment	HVAC	HVAC	none	none	none
	Lighting	controlled	controlled	variable	variable
	Hazards	dirt/salt/fog	dirt/salt/fog	dirt/salt/fog/heat/cold/physical	dirt/salt/fog/heat/cold/physical
Operational	Reparability	spares available	some spares available	no spares available	no spares available
	Decision Timelines	minutes – weeks	minutes – days	seconds - minutes	seconds - minutes
	Content	complex	complex	intermediate	simplified
	System Training	extensive - intermediate	extensive - intermediate	intermediate - minimal	intermediate - minimal
Security	Confidentiality	insider threat, packet sniffers	transmission interception	transmission interception	capture
	Integrity	viruses	transmission errors	transmission errors	spoofing
	Availability	denial of service	denial of service	jamming	capture, damage

Figure 4. Harmonized Tactical Edge Framework

3.2 Tailoring the Tactical Edge Framework

Ideally, all of the military Services' platforms fit nicely into one of the classes of TE environments defined in the TEF. In practice, while the majority of the platforms fit into one of the TEF's classes of environments, the flexibility to tailor the TEF's attribute values makes it more widely applicable. This need for flexibility was more noticeable after the FY 2008 harmonization process; the TEF values transitioned from focusing on high-level text descriptions (e.g., good connectivity) to focusing on numerical values (e.g., 85-100% connectivity). There can be agreement by the military Services on high-level descriptions, but disagreement on numerical values. Tailoring the TEF means it can be applied to situations where a platform does not fit into one of the four classes of TE environments defined in the non-tailored TEF, while retaining the benefits of using a common vocabulary to describe the classes of TE environments.

3.2.1 Process of Tailoring the Tactical Edge Framework

While the common vocabulary remains constant (i.e., the attributes that characterize classes of TE environments do not change), a user can adjust the specific values of the attributes to better reflect their platforms. For extreme differences in values, the tailored values can essentially result in an entirely new class of TE environment. The process of tailoring the TEF involves engaging SMEs and finding authoritative documentation, if possible, to support the SMEs' recommendations.

3.2.2 Results of Tailoring the Tactical Edge Framework

The first tailored version of the TEF was created for Special Operations Command (SOCOM). Special Operations Forces are unique in that their operations require very good connectivity, plenty of bandwidth, and spare parts must be available. The SOCOM-specific TEF values include >99% connectivity (even for dismounted users) and up to two megabits of bandwidth per second for dismounted users. The majority of the tailored values were consistent with the non-tailored TEF, which helped further validate the original values. The differences between the non-tailored TEF and SOCOM's tailored version are shown in Figure 5.

		Tactical Fixed Center		Tactical Mobile Center		Mobile Platform		Dismounted User	
		Non-Tailored	SOF	Non-Tailored	SOF	Non-Tailored	SOF	Non-Tailored	SOF
LAN Network	Connectivity	>85%	>99%	>85%	>99%	25-84%	>99%	5-24%	>99%
	Latency	<250 ms		<250 ms		>250ms		>250 ms	
	Bandwidth	128 kbps-100 Mbps		128 kbps-100 Mbps		1-128kbps		1-128 kbps	
	Reliability	>90%		>90%		>90%		>90%	
	Predictability	predictable		mostly predictable		less predictable		unpredictable	
WAN Network	Connectivity	>99%		85-99%	>99%	25-84%	>99%	<5%	>99%
	Latency	<250 ms		250-1000ms	<250ms	250-1000ms	>250ms	>1000ms	>250ms
	Bandwidth	<20 Mbps	<18 Mbps	128-1 Mbps	<4 Mbps	128-256 kbps	<4 Mbps	9.6-64 kbps	<2 Mbps
	Reliability	>90%		>75%		<75%		<75%	
	Predictability	predictable		predictable		less predictable		less predictable	
System	Standard User Interface	desktop – laptop		desktop - laptop		laptop - tablet - handheld		laptop - tablet - handheld	
	Processing	servers – workstations		servers - workstations		single workstations - handhelds		single workstations - handhelds	
	Storage	large data storage devices		large data storage devices		single hard drives		single hard drives	
	Ruggedness	few ruggedness considerations		few ruggedness considerations		many ruggedness considerations		many ruggedness considerations	
	Size	> 10 sq ft		> 10 sq ft		< 10 sq ft		< 3 sq ft	
	Weight	100s lbs		100s lbs		10 - 100 lbs		< 10 lbs	
	Power	grid, macro generator		generator - batteries		generator - batteries		batteries	
Environment	HVAC	HVAC	HVAC/ECU	none	HVAC/ECU	none	ECU	none	
	Lighting	controlled		controlled		variable		variable	
	Hazards	dirt/salt/fog		dirt/salt/fog		dirt/salt/fog/heat/cold/physical		dirt/salt/fog/heat/cold/physical	
Operational	Reparability	spares available		some spares available	spares available	no spares available	spares available	no spares available	spares available
	Decision Timelines	minutes – weeks	minutes – hours	minutes – days	minutes – hours	seconds - minutes		seconds - minutes	
	Content	complex		complex		intermediate		simplified	
	System Training	extensive - intermediate		extensive - intermediate		intermediate - minimal		intermediate - minimal	
Security	Confidentiality	insider threat, packet sniffers		transmission interception		transmission interception		capture	
	Integrity	viruses		transmission errors		transmission errors		spoofing	
	Availability	denial of service		denial of service		jamming		capture, damage	

Figure 5. Non-Tailored Tactical Edge Framework vs. Tailored for Special Operations Command

For the Navy, one of the major issues with the non-tailored TEF was that the majority of the Navy's fleet straddled two categories (i.e., Tactical Mobile Center and Mobile Platform). As a result, a hybrid class of TE environment was created in the Navy's tailored TEF, which included the characteristics of both classes of TE environments. The Navy's hybrid class replaces the non-tailored TEF's Mobile Platform class. While the TEF's vocabulary remained constant, the Navy-

specific TEF was developed in coordination with Navy SMEs to better represent the Navy's perspective.

Finally, within the Army, one of the major extensions of the TEF was adding a new class to characterize unmanned systems, including a subclass for Tier 1 Unmanned Systems (e.g., small unmanned ground sensors) and another subclass for Tier 2 Unmanned Systems (e.g., medium-to-large unmanned platforms, such as the Predator). The Army also updated the way in which the network was characterized from a Local Area Network/Wide Area Network distinction in the non-tailored TEF to specific communication architectures within and between TE environments. The differences between the Army's tailored TEF and the non-tailored TEF were so significant that the additional Unmanned Aircraft Systems classes and the method of characterizing the network were not rolled up into the non-tailored TEF; however, we believe that incorporating these differences into the non-tailored TEF warrants further consideration as the TEF continues to evolve.

For the Navy and Army, the tailored versions of the TEF continue to evolve. Current iterations are available on the TEF website, which is discussed in Section 5.

3.2.3 Implications of Tailoring the Tactical Edge Framework

Tailoring the values in the TEF can be problematic if solutions are mapped to entire TE environments (e.g., Mobile Platform). For example, consider a case where an existing chat service is operational in a Mobile Platform environment, which is characterized in the non-tailored TEF as having moderate bandwidth and connectivity constraints. If the Mobile Platform environment is tailored so the bandwidth and connectivity are severely constrained rather than moderately constrained, the chat service might not work in the tailored Mobile Platform environment with severe constraints.

This problem can be solved by mapping solutions to attributes rather than TE environments. If the chat service was mapped to moderate bandwidth and connectivity constraints rather than the Mobile Platform environment, the chat service would still be mapped to the moderately constrained non-tailored Mobile Platform environment; however, the chat service would no longer be mapped to the severely constrained tailored Mobile Platform environment. For an example, see Figure 6.

As mentioned previously, the ability to apply the TEF to situations that do not perfectly match the non-tailored TEF environments increases the TEF's applicability to a larger audience and solutions can accurately be mapped to any TE environment as long as it is described using the common vocabulary.

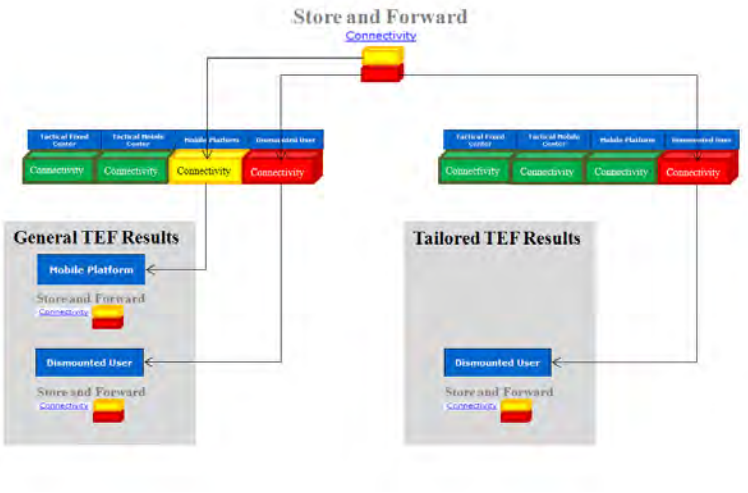

Figure 6. Accuracy of Design Patterns With the Tailored Tactical Edge Framework

4. Applications of the Tactical Edge Framework

To validate the TEF and support adoption, the TEF was applied to multiple DoD programs to demonstrate the TEF's contributions to realize services at the TE. This section describes the TEF's applicability throughout the service's acquisition lifecycle, including collecting users' requirements, documenting use cases, designing and developing a service, and managing a portfolio of services at the TE. (See Figure 7.)

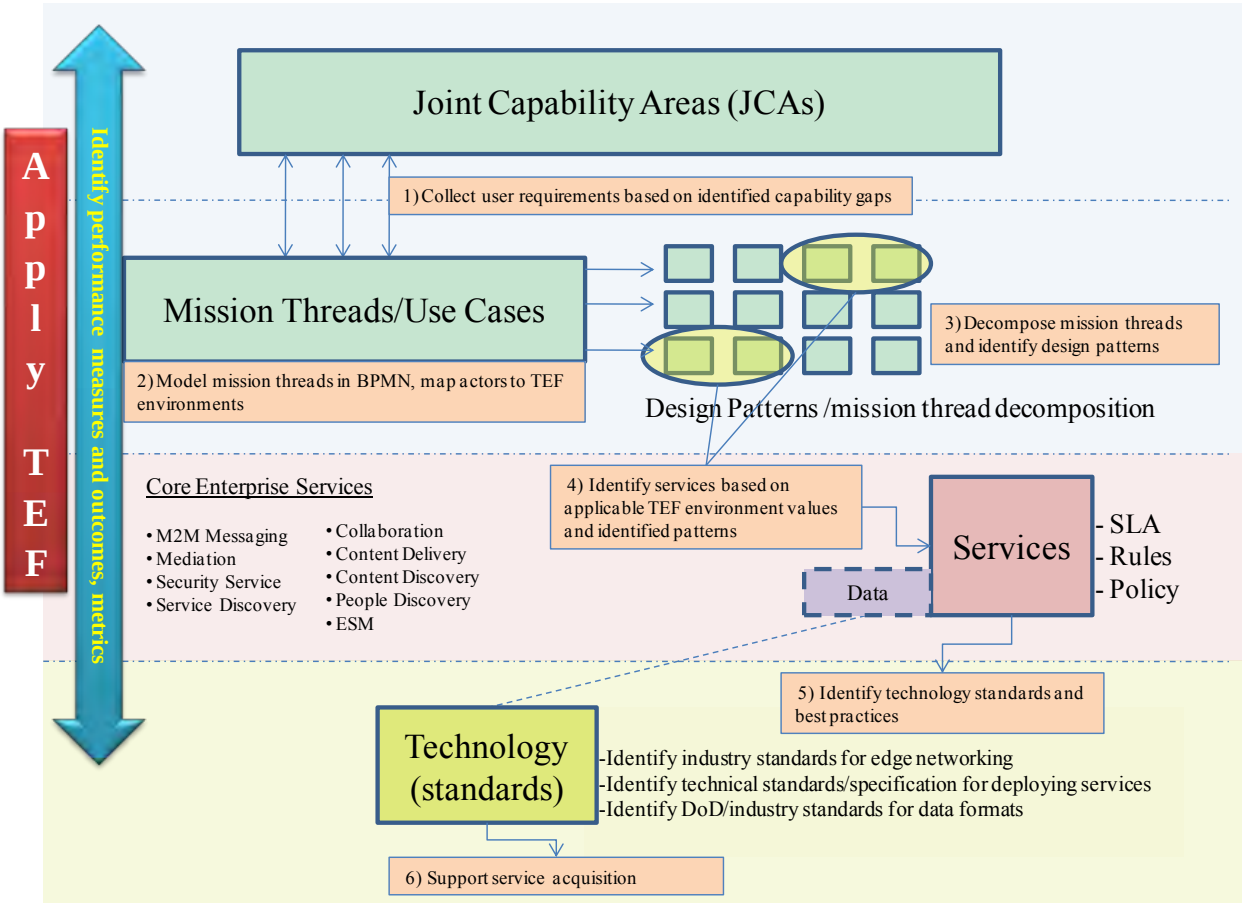

Figure 7. Applications of the Tactical Edge Framework

4.1 Collect User Requirements

In the process of defining strategic roadmaps, it is important to start by determining users' needs, defining the strategic goals for capability development, and using this information to identify capability gaps. While some capability gaps can emerge from the portfolio management processes, interviewing users is also a key component of identifying capability gaps and collecting requirements for future capabilities. The TEF can be utilized in this process to identify capability gaps by asking end-users about their functional operational needs, documenting mission threads (e.g., how they accomplish their tasks), and by inquiring about their TE environment's constraints using the TEF's common vocabulary and attribute values as guidance. (See Figure 7, Step 1.) This results in capturing end-user requirements in the context of the constraints of the environment. Once the necessary functions are identified for specific constrained environments, identifying where current or planned solutions might be inadequate becomes evident as TEF guidance, which includes a set of design patterns that are useful for specific environments. In this manner, capability gaps are flagged and can be documented (i.e., where current or planned services do not intersect with recommended guidance).

As an example, the TEF was employed by SOCOM's Tactical Local Area Network team during interviews with users at Tactical Special Operations Centers (TSOCs), including Special

Operations Command, South and Special Operations Command, Central. Prior to the interviews at TSOCs, questions were formulated that included queries about the TE environment and environment-specific attributes as defined by TEF. With these questions, the interviewers collected functional requirements and usage patterns that can feed into use cases related to specific TE environments. Including questions about the TEF's attributes in the interview process also helped validate the TEF with the SOCOM community.

4.2 Develop Mission Threads

Using the capability gaps and user requirements as a starting point, the next step is to document use cases through the development of mission threads, which in essence defines the Concept of Operations of the needed capability. Mission threads can include interaction patterns between actors. The actors in a TE mission thread can be characterized by using the TEF's common vocabulary and binning the actors into one of the four classes of TE environments (i.e., Tactical Fixed Center, Tactical Mobile Center, Mobile Platform, and Dismounted User). This is the equivalent of mapping each swim lane in a Business Process Modeling Notation [4] process flow diagram to the applicable TE environment. (See Figure 7, Step 2.) The benefit of this alignment is that it identifies the constraints that need to be taken into account within and across multiple classes of TE environments.

For example, the Core Enterprise Services to the Tactical Edge (CESTE) Focus Group is using the TEF to develop reference models for the DoD Chief Information Officer's (CIO) organization. The TEF was used by the CESTE Focus Group to map actors in a Joint Close Air Support (JCAS) scenario to the TEF's classes of TE environments. This mapping was used as part of identifying the Business Reference Model's content for the JCAS' architecture. Once this mapping was complete, the TEF vocabulary and the attribute values for each class of TE environment of the JCAS' actors were immediately available for use as non-functional performance metrics. The values were employed as metric constrains and were used to define and populate the Performance Reference Model for the JCAS' architecture.

4.3 Identify Design Patterns

Aligning mission threads with the TEF allows one to identify applicable design patterns and other guidance, which enables the delivery of effective services to support the mission threads. Design patterns are first associated with the TEF's attribute constraints that they can help mitigate [3]. (See Appendix C.) For example, a design pattern can be associated with intermittent connectivity and low bandwidth. Services are aligned with the TEF's classes of environments in which they were designed to function. (See Figure 7, Step 3.)

For example, the TEF was used by the Net-Enabled Command Capability (NECC) program to characterize Disconnected, Intermittent, and Limited (DIL) environments and define the interface between the Global Information Grid Computing Nodes (GCN), including enterprise GCNs (e.g., Defense Information Systems Agency's [DISA] Enterprise Computing Center) and local GCNs (e.g., DIL environments).

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[4] Business Process Modeling Notation, as defined by the Object Management Group ™.

MITRE recommended an adaptation of the common vocabulary to characterize NECC's local GCNs in order to differentiate between the classes of local GCNs from those of enterprise GCMs, and to further tailor the solution sets being developed for the local GCNs to differentiate them from those being adopted for enterprise GCNs. These recommendations are documented in the paper, "NECC Disconnected, Intermittent, Low Bandwidth Requirements and Architectural Approaches" (NECC Disconnected, Intermittent, Low Bandwidth Requirements and Architectural Approaches 2008). In addition, NECC's Architecture Framework document adopted the DIL characterization in its definition of the operational environment [5].

4.4 Identify Services

Aligning a mission thread's actors with the applicable TEF class of environment allows for the identification of services and design patterns that provide options to help in mitigating the constraints for a particular TE mission thread. The design patterns can then be incorporated into service specifications to ensure that the results can provide the needed capabilities given the constraints of the classes of TE environments. In addition, aligning service solutions to the TEF (i.e., mapping service solutions to the classes of TE environments in which they currently, or are intended to, operate) allows Portfolio Managers (PMs) to assess the existing portfolio to determine if a newly identified capability need can be met with existing solutions, and if such solutions will support use in the intended TE environment. In other words, mapping services to TEF classes of environments allows PMs to look across an existing portfolio of services and COTS tools to identify existing solutions built with the necessary underlying assumptions about constraints. (See Figure 7, Step 4.) The TEF classes of environments allow for comparisons across DoD components and various types of TE platforms that otherwise can have appeared as distinct entities.

For example, under the CESTE Focus Group, CES were identified from the information flows modeled in the JCAS scenario. The TEF's design patterns were then used to identify specific service tailoring needed for each JCAS actor, as required by their class of TE environment. This mapping was used to define the Service Reference Model and identify required services for the JCAS architecture.

4.5 Identify Technology Standards and Best Practices

Best practices and standards are a crucial enabler of interoperable systems because they promote a reasonable degree of consistency across service implementations. One challenge in employing this guidance is determining what is applicable; it is often difficult to identify the specific guidance that applies to a particular situation. For example, a developer might focus on defining a data staging strategy for users who have connectivity only 10-40% of the time. The TEF can be used to organize best practices and standards for developers. Within the TEF, mapping the classes of TE environments to the best practices and standards organizes the guidance so it can be navigated by a particular TE environment or constraint. (See Figure 7, Step 5.) The TEF allows developers to identify specific guidance based on a particular context (e.g., user interfaces for dismounted users). The guidance can also be tailored to address a particular challenge in a TE environment. The intent is to provide a TE perspective on the multiple volumes of guidance so a user developing services for the TE can employ the TEF to navigate through the material and identify relevant and possibly tailored guidance. The guidance is aligned with the constraints of

the TE environment to support binning the guidance by the constraints as well as clustering it by the classes of TE environments.

For example, this approach is being employed by Net-Centric Enterprise Solutions for Interoperability (NESI), specifically within NESI's Part 4 on Node Guidance. The TEF was used to define operational environment characteristics for the Global Information Grid's core and the TE; the common vocabulary was used to define criteria so relevant guidance and best practices for implementing the node capabilities within NESI can be specified for each operational environment.

4.6 Support Service Acquisition

A challenge with acquiring systems for the TE is identifying quantifiable criteria to assess the readiness of the systems that will operate within TE environments. Aligning mission threads to the TEF provides a means to characterize the constraints of the classes of TE environments using a common vocabulary and to derive the non-functional requirements that can be part of a Request for Proposal (RFP). (See Figure 7, Step 6.) These non-functional requirements characterize the unique considerations of each TE environment in which the system will be deployed. The TEF also provides a common means to assess bidder's submissions. In the proposal creation process, bidders can describe the classes of TE environments for which their solutions will provide capabilities and align them to the non-functional requirements in the RFP. This simplifies the proposal evaluation process by grouping the proposed services into a common set of bins to characterize and assess the proposals. Furthermore, quantifying the constraints of the TE environments through common attribute values helps identify design patterns against which the proposed solutions can be compared.

4.7 Support Portfolio management

To support portfolio management, the CESTE Focus Group will deliver a plan to explore issues associated with the deployment of services at the TE, a set of reference models, and departmental guidance for delivering Core Enterprise Services to and throughout the TE. The value of applying the TEF to the reference models' development is the TEF's common vocabulary (i.e., set of attributes) characterize different aspects of the classes of TE environments and provides the basis for an initial service and performance TE ontology.

5. Tactical Edge Framework Website

As shown in the examples in Section 4, the TEF can be applied throughout the process of analyzing, designing, and developing TE services. To encourage the adoption and re-use of the TEF, the FY 2008 ESE Capstone activity's products were posted on an interactive website. (See Figure 8.) The website is currently available on MITRE's internal network (http://calypso.mitre.org/tacticaledgeframework) and it can be accessed at a secure external website for both government and MITRE access (https://yukon2.mitre.org/tacticaledgeframework/).

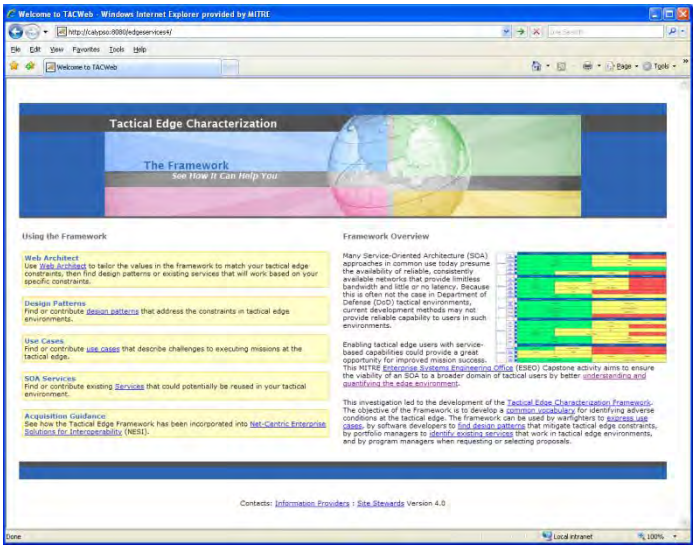

Figure 8. Main Page of the Tactical Edge Framework Website

The main page provides an overview of the TEF, describing why it was developed and what it can be used for. From the main page, users can access the latest version of the TEF, design patterns, existing services, and examples of TE use cases. These features allow MITRE to provide the most up-to-date tailored versions of the TEF, an overview of the existing services that were designed to work in the TEF's classes of environments, and access to a significant repository of cutting-edge design patterns intended to overcome common constraints at the TE.

In addition to finding content, users can also contribute content to the website. We hope the website's content will become richer and more expansive as awareness of the website increases and government users add to it. After a user is approved for an account, he or she can:

- Add use cases that describe user requirements and TE constraints.
- Add design patterns and associate them with the TEF's common vocabulary.
- Add services and bin them by the type of TE environment in which they are intended to function.

As users contribute and search for content, they are essentially using processes similar to those used by MITRE's ESE Capstone activity team in applying the TEF in FY 2008 (i.e., capturing user requirements, identifying design patterns to overcome constraints, and consolidating the services designed to work in the TEF's classes of environments).

An additional feature provides a powerful method to search for relevant design patterns. Using the Web Architect model, users can choose specific classes of TE environments and attributes from the TEF and tailor the constraints to match their classes of TE environments, to retrieve the most accurate results for a specific TE environment. (See Figure 9.)

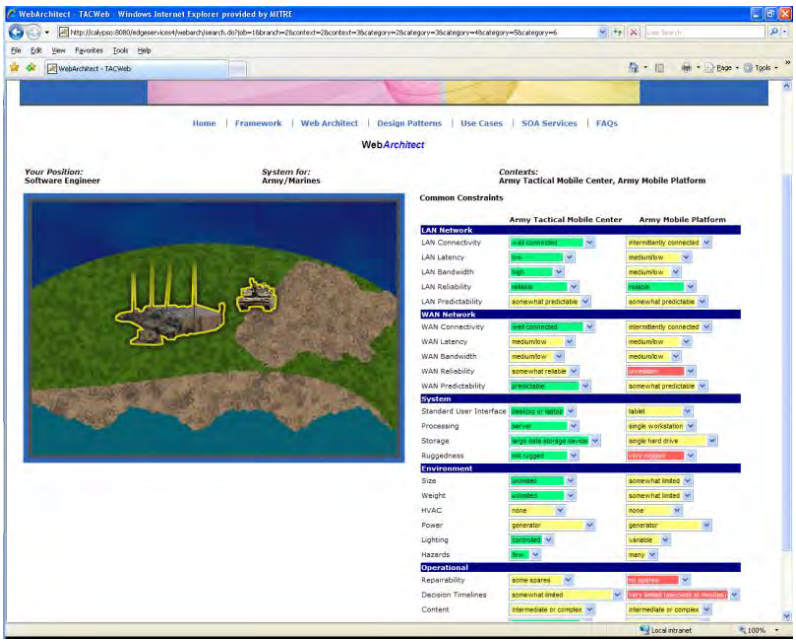

Figure 9. Using Web Architect to Find Tailored Guidance

In the future, we hope the TEF website will enable users of the TEF to more readily capture TE users' requirements, identify design patterns to overcome TE constraints, consolidate TE services, and more.

6. Conclusions and Recommendations

The primary objective of the TEF is to provide a common vocabulary to characterize TE environments so the TE characteristics can be quantified and solutions can be identified to explicitly address them. Subsequently, as the DoD's components deliver services to the TE, the TEF's common vocabulary and use of consistent design patterns will promote interoperability across component-specific implementations.

To support this objective, the focus of MITRE's ESE Capstone activity in FY 2008 was to socialize the TEF and facilitate its transition to the DoD. The socialization of the TEF across the DoD's components and the component's commands resulted in the validation and evolution of the TEF.

Another focus of the FY 2008 activity was to apply the TEF across multiple DoD programs to demonstrate its value. This resulted in the initial adoption of the TEF across several DoD programs. Along with this progress toward the bottom-up adoption of the TEF, it is imperative that the use of the TEF and its common vocabulary be further institutionalized at a departmental level. In support of this, we recommend the following:

- Joint Staff and doctrinal leads from the components should adopt the TEF to establish DoD-wide definitions for the classes of TE environments and use the TEF's common vocabulary to characterize them.

- The DoD CIO and the Net-Centric (NC), Command and Control, and Battlespace Awareness Capability PMs should employ the TEF to define Service and Performance Reference Models in order to establish an NC Enterprise Architecture.
- DISA's Net-Centric Enterprise Services and NECC, in conjunction with the Service-specific PoR developing enterprise services (e.g., Navy Consolidated Afloat Networks and Enterprise Services, Army System-Of-Systems Common Operating Environment, Marine Corps Enterprise Information Technology Services, and Air Force Air and Space Operations Center as a Weapon System) should use the TEF to define and document interfaces and design patterns to achieve federation and meet Quality of Service requirements across Service-specific TE platforms.

The adoption of a common characterization of the TE and the use of consistent design patterns across the DoD will minimize architectural differences across the DoD's components and promote interoperability across component-specific service implementations at the TE.

7. References

1. Dally, K. et al.,"Tactical Edge Gateway Functional Taxonomy," October 2007, ESE Capstone Product, The MITRE Corporation, MTR 070286.

2. Dandashi, F. et al., "Tactical Edge Characterization Framework, Volume 1: Common Vocabulary for Tactical Environments," November 2007, ESE Capstone Product, The MITRE Corporation, MTR 070331.

3. Dandashi, F. et al., "Tactical Edge Characterization Framework, Volume 2: Design Patterns for Tactical Environments," September 2007, ESE Capstone Product, The MITRE Corporation, MTR 070326.

4. Net-Enabled Command Capability, "NECC Disconnected, Intermittent, Low Bandwidth Requirements and Architectural Approaches," 2008.

5. Net-Enabled Command Capability, "NECC Software Architecture Framework, Software and Physical Views," 2008.

Appendix A: Harmonization of the Tactical Edge Framework and Central Command's "Disadvantaged User" White Paper

- Class names were merged:
  - Tactical Edge Framework's (TEF's) "fixed center" and Central Command's (CENTCOM) "tactical fixed" became "tactical fixed center."
  - TEF's "mobile center" and CENTCOM's "tactical semi-fixed" became "tactical mobile center."
  - TEF's "mobile swarm" and CENTCOM's "mobile (mounted and maritime)" became "mounted user." [Note: After the harmonization process, this class was renamed "mobile platform."]
  - TEF's "dismounted" and CENTCOM's "mobile-dismounted" became "dismounted user."
- High-level categories were merged:
  - TEF categories: network, resource, user interface, and security threats.
  - CENTCOM categories: physical and environment, communications, and operational/other.
  - Harmonized categories: network, system, environment, operational, and security.
- Attribute values were merged:
  - TEF values: general characterization (e.g., high, medium, and low).
  - CENTCOM values: specific values.
  - Harmonized values: described as a range between two specific values.
- Standard terms of reference were replaced with unofficial attribute names:
  - Size, Weight, and Power terminology was used.
  - Confidentiality, Integrity, and Availability terminology was used in the security category.
  - CENTCOM's spectral environment attribute was combined with TEF's predictability attribute.
  - Heating, Ventilation, and Air Conditioning and environmental constraints remained because Special Operations Command considered them to be important issues. The Communications Architecture column from CENTCOM's TEF (i.e., wideband satellite communications, cable, fiber, wireless, etc.) was adequately captured by the Local Area Network/Wide Area Network (LAN/WAN) aspects in the harmonized TEF. It was noted that line-of-site can be a point-to-point connection that does not have a LAN/WAN interface.

Appendix B: Authoritative Definitions of Common Vocabulary Terms

Network

- Connectivity: "The ability to exchange information by electronic means." The Tactical Edge Framework (TEF) measures connectivity using the frequency with which the network is available. This can be quantified as a percentage of time when connectivity is available.
- Bandwidth: "The difference between the limiting frequencies of a continuous frequency band expressed in hertz (i.e., cycles per second). The term bandwidth is also loosely used to refer to the rate at which data can be transmitted over a given communications circuit. In the latter usage, bandwidth is usually expressed in either kilobits per second or megabits per second." The TEF measures bandwidth in kilobits or megabits per second.
- Latency: Definition not in Joint Publication 1-02. The TEF uses latency to mean the amount of time it takes a packet of data to travel from one point to another in a network. It is measured in milliseconds.
- Reliability: Definition not in Joint Publication 1-02. The TEF uses reliability to indicate whether the delivery of a message in a network is guaranteed or not. It is measured as the percent of time the delivery is guaranteed. A lack of reliability can Result from a resource's failure or packet loss.
- Predictability: Definition not in Joint Publication 1-02. The TEF uses predictability to mean the degree that the network environment can be anticipated (e.g., spectral environment, delivery of messages, security threats, lighting constraints, etc.) at any given time. A discrete value of predictable, mostly predictable, less predictable, or unpredictable is used in the TEF to indicate predictability.

System

- System Processing: "A system of operations designed to convert raw data into useful information." The TEF provides a measure of processing power by binning processing power into handheld, single workstation, multiple workstations, or servers. A more specific measurement can be the rate at which a computing device performs operations, (i.e., the clock rate [speed] of the Central Processing Unit).
- Storage: "A device consisting of electronic, electrostatic, electrical, hardware or other elements into which data may be entered, and from which data may be obtained as desired." The TEF provides a measure of storage by binning storage into handheld memory, single data storage device, and large data storage device. A more specific measurement can be gigabytes.
- Standard User Interface (SUI): Definition not in Joint Publication 1-02. The TEF uses SUI to mean the type of device being used and the corresponding standard style of the user interface for the device. The TEF bins SUI into handheld, tablet, laptop, and desktop.
- Ruggedness: Definition not in Joint Publication 1-02. The TEF uses ruggedness to mean a device's ability to survive the environment's hazards. The TEF bins ruggedness into the number of environmental constraints that a device needs to withstand (i.e., few, some, and many ruggedness considerations).

- Size: 1) "Available Payload: The passenger and/or cargo capacity expressed in weight and/or space available to the user." Or 2) "Man Portable: Capable of being carried by one man. Specifically, the term may be used to qualify: 1. Items designed to be carried as an integral part of individual, crew-served, or team equipment of the dismounted soldier in conjunction with assigned duties. Upper weight limit: approximately 14 kilograms (31 pounds.) 2. In land warfare, equipment that can be carried by one man over long distance without serious degradation of the performance of normal duties." The TEF bins size into <3, <10, or >10 square feet of space available.
- Weight: 1) "Available Payload: The passenger and/or cargo capacity expressed in weight and/or space available to the user."Or 2) "Man Portable: Capable of being carried by one man. Specifically, the term may be used to qualify: 1. Items designed to be carried as an integral part of individual, crew-served, or team equipment of the dismounted soldier in conjunction with assigned duties. Upper weight limit: approximately 14 kilograms (31 pounds.) 2. In land warfare, equipment that can be carried by one man over long distance without serious degradation of the performance of normal duties." The TEF bins weight into <10, 10-100, or hundreds of pounds.
- Power: Definition not in Joint Publication 1-02. The TEF uses power to mean the type of power available. The TEF bins power into battery, generator, macro generator, or grid.

Physical Environment

- Heating, Ventilation, and Air Conditioning (HVAC): Definition not in Joint Publication 1-02. The TEF uses HVAC to mean the availability of HVAC or an Environmental Control Unit (ECU). Possible values in the TEF are HVAC, ECU, or none.
- Lighting: Definition not in Joint Publication 1-02. The TEF uses lighting to mean the typical lighting constraints in an environment. The lighting constraints can be abstracted into controlled lighting (e.g., an office) or variable lighting (e.g., day/night or indoor/outdoor).
- Hazards: “A condition with the potential to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or mission degradation.” The TEF provides a list of the most common types of hazards in each environment (e.g., heat, cold, dirt, fog, and salt).

Operational

- Reparability: “Reparable item: An item that can be reconditioned or economically repaired for reuse when it becomes unserviceable.” The TEF measures reparability using the number of spare parts available for replacement in case of failure (i.e., spares available, some spares available, and no spares available).
- Decision Timelines: “Reaction time: The elapsed time between the initiation of an action and the required response.” The TEF measures decision timelines by binning them into seconds to minutes, minutes to hours, minutes to days, or minutes to weeks.
- Content: “Data: The representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means. Any representations such as characters or analog quantities to which

meaning is or might be assigned." The TEF measures data complexity by binning it into complex, intermediate, and simplified.

- System Training: Definition not in Joint Publication 1-02. The TEF uses system training to mean the amount of training a user receives on how to use the application, which is a combination of the length and type of training and the frequency of use. System training is binned into minimal, intermediate, and extensive.

Security

- Information Assurance (IA): "Measures that protect and defend information and information systems by ensuring their availability, integrity, authentication, confidentiality, and non-repudiation." This includes providing for the restoration of information systems by incorporating protection, detection, and reaction capabilities.
- Confidentiality: Definition not in Joint Publication 1-02. The TEF uses confidentiality to mean assurance that information is not disclosed to unauthorized persons, processes, or devices. The TEF provides a list of the most common types of risks to confidentiality in each environment.
- Integrity: Definition not in Joint Publication 1-02. The TEF uses integrity to mean the quality of an information system reflecting the logical correctness and reliability of the operating system, the logical completeness of the hardware and software implementing the protection mechanisms, and the consistency of the data structures and occurrences of the stored data. In a formal security mode, integrity can be interpreted more narrowly to mean protection against unauthorized modification or the destruction of information. The TEF provides a list of the most common types of risks to integrity in each environment.
- Availability: Definition not in Joint Publication 1-02. The TEF uses availability to mean timely, reliable access to data and information services for authorized users. The TEF provides a list of the most common types of security risks to availability in each environment.

All definitions in quotations are from Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms. As amended through 30 May 2008 (http://www.dtic.mil/doctrine/jel/doddict).

Appendix C: Cross Referencing Common Vocabulary With the Tactical Edge Gateway Functionality Taxonomy

The following are approximate mappings from the Tactical Edge Framework to the Tactical Edge Gateways Functional Taxonomy [1]:

- Bandwidth – Capacity
- Reliability – Signal, Statistical Availability
- Predictability – Station Time
- Confidentiality – Access
- Integrity – Traffic
- Availability – Threat Survivability
- Storage – Storage
- Size, Weight, and Power (SWaP) – SWaP Suitability, Existing Payloads
- Network and Security category attributes – Operational Enabling attributes
- System, Environment, and Operational category attributes – Operational Fit attributes
- TEF classes – Gateway Platforms.

Appendix D: Acronym List

CENTCOM	Central Command
CES2TE	Core Enterprise Services to the Tactical Edge
CIO	Chief Information Officer
COTS	Commercial Off-the-Shelf
CPMO	Component Program Management Office
DIL	Disconnected, Intermittent, and Limited
DoD	Department of Defense
ECU	Environmental Control Unit
ESE	Enterprise Systems Engineering
FY	Fiscal Year
GCN	Grid Computing Node
HVAC	Heating, Ventilation, and Air Conditioning
IA	Information Assurance
LAN	Local Area Network
NC	Net-Centric
NECC	Net-Enabled Command Capability
NESI	Net-Centric Enterprise Solutions for Interoperability
PoR	Programs of Record
RFP	Request for Proposal
SME	Subject Matter Experts
SOCOM	Special Operations Command

SOE	Service-Oriented Environment
SUI	Standard User Interface
TE	Tactical Edge
TEF	Tactical Edge Framework
TSOC	Tactical Special Operations Centers
WAN	Wide Area Network