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Toward an Operational Proxy for Acquisition Workforce Quality: Measuring Dynamic Knowledge and Performance at the Tactical Edges of Organizations

13 October 2012

by

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Graduate School of Operational & Information Sciences, and
Graduate School of Business & Public Policy

Naval Postgraduate School

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Abstract

The efficacy of defense acquisition is highly dependent upon acquisition workforce (AWF) quality, but assessing such quality remains a major challenge, particularly given the knowledge-intensive and dynamic nature of acquisition organizations and processes. Hence, it is difficult to gauge—much less predict—the impact of leadership interventions in terms of policy, process, regulation, organization, education, training, or like approaches. Building upon the development and application of Knowledge Flow Theory over the past couple of decades, we have developed a state-of-the-art approach that enables us analyze, visualize, and measure dynamic knowledge and performance. The main idea is to apply this approach inwardly to measure the dynamic knowledge and performance of acquisition processes (e.g., within contracting and project management organizations), but we also look outwardly (e.g., at warfare processes at the tactical edges of military combat organizations) to conceptualize an operational proxy for acquisition workforce quality: *end customer performance*. This proxy offers its best potential to complement, not replace, other metrics in use, development, and conceptualization today, but it arguably concentrates on one of the most important AWF quality determinants: how acquired systems affect operational performance.

Keywords: workforce quality, leadership interventions, Knowledge Flow Theory, end customer performance, revolutionary dynamic knowledge, and performance measures

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I. Introduction

Acquisition is big business. The U.S. Department of Defense (DoD) alone routinely executes 12-figure budgets for research, development, procurement, and support of weapon systems and other military products and services (Dillard & Nissen, 2005). Acquisition is also a knowledge-intensive business. In addition to myriad laws governing federal acquisition in the U.S., a plethora of rules and regulations specify—often in great detail—how to accomplish the planning, review, execution, and oversight of defense acquisition programs, large and small, sole-source and competitive, military and commercial (Dillard, 2003).

As a result in part—and due to high complexity, multiple stakeholders, goal incongruence, open process execution, and large pecuniary rewards for some participants—acquisition has been a problematic business too. Seemingly every decade, acquisition problems must be addressed by another Blue Ribbon panel and reformed yet again. The Better Buying Power Initiatives (BBPI), as a recent instance, mandate efficiency and productivity improvements in five acquisition business areas: (1) affordability and cost growth, (2) productivity and innovation in industry, (3) competition, (4) tradecraft in services acquisition, and (5) non-productive processes and bureaucracy (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 2010). These initiatives focus principally on incentives for and interactions with contractors. The Defense Acquisition Workforce Improvement Act (DAWIA), as another instance, was signed into law in 1990 and emphasizes the education, training, and certification of people in the acquisition workforce (AWF). Of course, the two leadership interventions are related: people in the AWF need to know how to effect the kinds of efficiency and productivity improvements mandated via the BBPI.

These characteristics of acquisition emphasize the criticality of quality in the AWF itself: with so much at stake, and in such a knowledge-intensive environment, a high-quality workforce is essential to competent and professional acquisition performance.

These characteristics also elucidate the central role played by people and organizations in the AWF: people must be knowledgeable and work effectively—not only in terms of their own professional acquisition activities but also with many others in acquisition and customer organizations—in order to accomplish key objectives and ensure timely, affordable, and responsive delivery of products and services to fighting and support units, at home and abroad. Indeed, we understand well how the efficacy of defense acquisition is inextricably dependent upon workforce quality. Hence, leadership interventions along these lines appear to be highly appropriate and on target.

Assessing the impact of interventions such as these is a challenge, however (Assistant Secretary of the Navy for Research, Development, and Acquisition [ASN(RDA)], 2011a, 2011b). It's unclear whether the relatively recent BBPI, for instance, have had sufficient time to produce measurable impact. Even after two decades of the DAWIA, as another instance, efficacy remains challenging to assess, for many extant measures (e.g., *number of Defense Acquisition University graduates, procurement lead times, program cost growth*) fail to account for critical aspects of the AWF and important impacts on acquisition performance. Indeed, it is difficult to gauge—much less predict—the impact of any leadership interventions along these lines (e.g., how much better the AWF has become, or even *if* it is improving over time). Hence, the impact of any particular leadership intervention is left largely to anecdote and optimism. To help trim acquisition budgets and guide leadership, an improvement in assessing leadership initiatives and interventions is needed.

Since acquisition is a knowledge-intensive endeavor (Snider & Nissen, 2003), the knowledge stocks of people comprising the AWF represent likely indicators of quality (e.g., *education levels, training courses, years of experience, certification* *levels*). However, such indicators are relatively static, pertaining to levels of knowledge that change comparatively slowly (Nissen, 2006a). In contrast, acquisition laws, rules, and regulations are revised frequently, and acquisition knowledge can change abruptly and render obsolete even huge stocks over time. Indeed, this dynamic acquisition environment requires members of the AWF to sustain career-long learning and knowledge development just to remain proficient as acquisition professionals. Thus, as indicators of AWF quality, static knowledge stocks appear to be out of phase with the highly dynamic nature of the acquisition environment.

Moreover, acquisition organizations experience persistent flux (Snider & Nissen, 2003). We understand well that no two acquisition projects, programs, organizations, customers, or requirements are completely alike. Hence, even well-educated and -trained people, with appropriate certification levels and years or decades of acquisition experience, must continually learn afresh and expand their knowledge further with each new assignment. Likewise, it is clear that most acquisition organizations form and reform with new people (e.g., via personnel transfer, turnover, retirement, promotion) continuously and that end customer needs shift perennially (especially at the tactical edges of warfare organizations). Due to such discontinuous membership (Ibrahim & Nissen, 2007), even these educated, trained, certified, and experienced people must learn repeatedly to trust and work effectively with many others—each time someone new joins or leaves a particular acquisition organization, and each time a novel product, service or customer is involved. Thus, dynamic knowledge also appears to be an important AWF quality indicator.

Further, the pace of change in both information technologies and military operations causes this importance of dynamic knowledge to apply in particular where information systems (IS) are acquired to support people at the tactical edges of warfare organizations. Not only must acquisition personnel be competent in their professions—including the acquisition and maintenance of new acquisition knowledge and skills—and continually learn afresh amidst constant organizational flux, but they must also keep pace with incessant technological change and satisfy customers' dynamic needs. Even highly competent professionals executing internal acquisition processes perfectly can fail to satisfy end customers' materiel or service needs. This presents a huge challenge in terms of assessing AWF quality.

Building upon the development and application of Knowledge Flow Theory (KFT) over the past couple of decades (e.g., see Nissen, 2006b), we have developed a state-of-the-art approach that enables us to analyze, visualize, and measure dynamic knowledge and performance. This measurement-based approach offers potential to overcome the limitations of static measures, as previously summarized, by focusing inwardly on the dynamics of knowledge important to professional and effective acquisition performance. The main idea is to measure the dynamic knowledge and performance of acquisition processes (e.g., within contracting and project management organizations). This would represent a substantial step forward in terms of acquisition research.

Further, leveraging complementary research in command and control (C2; Nissen & Gallup, 2012), we see potential to use this same measurement-based approach to also look outwardly at the dynamics of knowledge important to professional and effective warfare performance. Although the specific kinds of knowledge required for effective warfare will clearly differ from those essential for proficient acquisition, the approach is similar. The main idea is to measure the dynamic knowledge and performance of warfare processes (e.g., at the tactical edges of military combat organizations). This would represent a substantial step forward in terms of C2 research.

Moreover, we seek to link these inward and outward focusing approaches to conceptualize an operational proxy for AWF quality: *end customer performance*. In addition to measuring the dynamic knowledge and performance of key people and organizations associated with IS acquisition, for instance, we wish to assess AWF quality by also measuring the dynamic knowledge and performance of primary beneficiaries of such systems acquisition: end customers operating at the tactical edges of warfare organizations. This proxy offers its best potential to complement, not replace, other metrics in conceptualization, development, and use today, but it arguably concentrates on one of the most important AWF quality determinants: how acquired systems affect operational performance. Two fundamental research questions follow accordingly:

- How can dynamic knowledge and performance metrics be applied to assess acquisition workforce quality?
- How can dynamic knowledge and performance metrics be extended to the tactical edges of warfare organizations?

In this exploratory study, we examine fast-changing IS acquisition from the perspective of warfare at the tactical edge, and we consider dynamic knowledge and performance measures to both complement and contrast with extant, engineering-oriented metrics used to specify and assess most acquired systems today. We begin with a summary of KFT and measurement and then follow with the research method guiding the study. Preliminary results follow and suggest considerable promise, particularly where acquisition personnel and organizations can learn and track how changing system characteristics correspond with operational performance at the tactical edges of warfare organizations over time. This technical report concludes with key observations, limitations, and an agenda for continued research along these lines.

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II. Knowledge Flow Theory and Measurement

The dynamic nature of knowledge indicates that both stocks and flows are important (Direickx & Cool, 1989). Knowledge stocks have been comparatively straightforward to measure historically; metrics pertaining to education levels, training courses, years of experience, certifications, and like knowledge-oriented factors are employed broadly. Alternatively, knowledge flows have been comparatively much more difficult to assess; metrics pertaining to dynamic knowledge—particularly at the group and organization levels—are more elusive. The development and application of KFT (e.g., see Nissen, 2006b) over the past couple of decades has augmented the set of tools and techniques available to analyze, visualize, and measure dynamic knowledge and performance in the organization.

KFT is founded on a set of 30 principles that characterize dynamic knowledge. Such principles are actionable and empirical, and they support the diagnosis of workflow and knowledge-flow process pathologies, visualization of improvement interventions, and measurement of dynamic knowledge and performance gains (Nissen, 2006a). Dynamic knowledge is delineated via five-dimensional (5D) vector space. Knowledge-flow vectors carry measurements and elucidate diagnostic inferences pertaining to the people, processes, and organizations associated with knowledge work. Figure 1 illustrates the idea.

Briefly, the vertical axis “Explicitness” characterizes the nature of knowledge along a tacit-explicit continuum. Tacit knowledge implies understanding and know-how/why, and it is associated most closely with the experiences of people (e.g., stemming from job assignments, mentoring, and teamwork) and routines of organizations (e.g., including culture, process, and ritual). Explicit knowledge implies awareness and know-who/what/where/when, and it is associated most closely with artifacts (e.g., documents, formulae, software). Generally, the more tacit the knowledge, the greater its appropriability and potential impact on positive performance becomes (Saviotti, 1998). One can measure knowledge explicitness using ordinal, interval, or ratio scales.

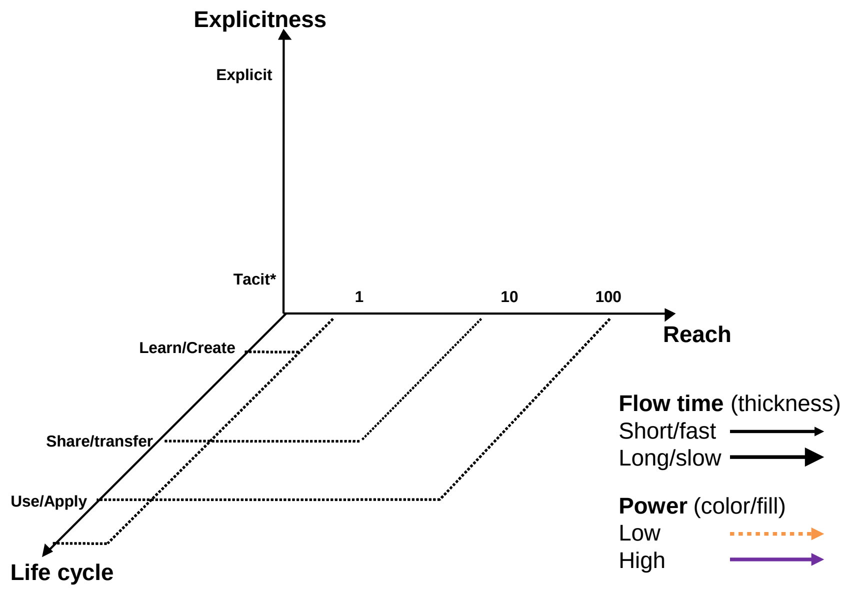

Figure 1. 5D Knowledge Flow Diagram

The horizontal axis "Reach" characterizes how broadly knowledge is known and shared in an organization. Here we operationalize reach in terms of the number of people in an organization who have access to and can employ any particular chunk of knowledge, but we could view reach in terms of organizational levels instead (e.g., individual, group, organization, interorganization). Generally, the broader the reach of knowledge, the greater its amplification and potential impact on positive performance becomes (Nonaka, 1994). Measurements can be made using ordinal, interval, or ratio scales.

The axis "Life cycle" characterizes what is being done with a particular chunk of knowledge at some specific point in time. Here we include three activities: (1) some individual in the organization learns or creates new knowledge; (2) he or she shares existing knowledge with or transfers it to other people in the organization; and (3) one or more people in the organization use or apply existing knowledge to accomplish work. Generally, knowledge does not become useful until it is used or applied (Pfeffer & Sutton, 1999). Measurements can be made using categorical or ordinal scales.

Because visualization beyond three dimensions is difficult, we represent the dimension "Flow time" in terms of the thickness of lines used to delineate vectors. As shown in the key to the right of Figure 1, relatively thin lines are used to delineate short and fast knowledge flows, whereas comparatively thick lines represent knowledge that takes a long time and flows slowly. Generally, the more quickly that knowledge flows (e.g., across people, organizations, places, times), the greater its potential impact on positive performance becomes (Nissen, 2002). Measurements can be made using ordinal, interval, or ratio scales.

The dimension "Power" is represented similarly in terms of line style used to delineate knowledge-flow vectors. Knowledge that flows with relatively low power—this corresponds with relatively low performance levels of organizational activities enabled by the knowledge—is delineated through orange, dotted lines, whereas knowledge flows exhibiting high power—and hence enabling high performance—are delineated via purple, solid lines. Measurements can be made using ordinal, interval, or ratio scales.

Integrating these five dimensions graphically and analytically generates a 5D vector space to examine dynamic knowledge. Such 5D space and examination schemes are completely general: they can be applied to any dynamic knowledge in any organizational domain (e.g., acquisition, command and control, software engineering).

As an example of use and application, consider Figure 2, which illustrates an important knowledge flow desired by the organization. Point A represents one individual in the organization who learns something new (to that organization) or creates entirely new knowledge. In terms of the 5D space, this represents tacit knowledge that is created by an individual (i.e., one person); hence, its position at the bottom-back corner of the diagram.

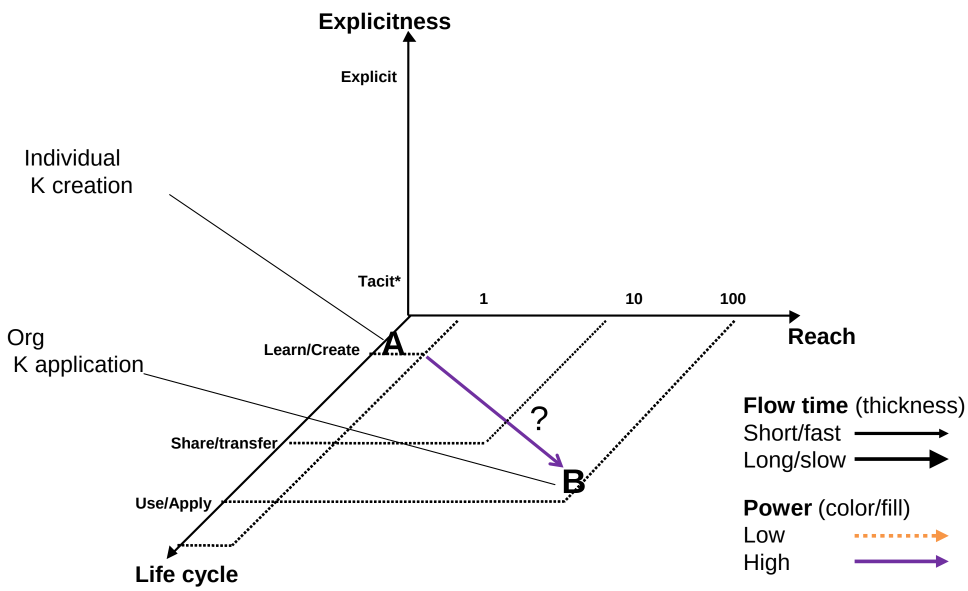

Figure 2. Knowledge Creation and Application Needs

In the acquisition domain, for instance, consider that such new knowledge could pertain to a technique for reducing the acquisition time for an important IS needed in the field. Because information technology (IT) advances so quickly—outpacing the ability of many acquisition organizations to develop and field systems responsively—the organization views this new knowledge created at Point A as important, and it would like to see such knowledge shared with and applied by all 100 people in that organization who work with IT.

Such application by 100 people in the organization is represented by Point B. The thin, purple, solid vector connecting Points A and B represents the desired knowledge flow: the organization wishes for such knowledge to flow quickly and with high power (e.g., enabling all 100 people at Point B to work, within one day, at the same performance level as the innovative individual at Point A). This represents a 5D knowledge flow vector. A question mark in the figure next to the vector indicates that such a fast, powerful knowledge flow is desired by the organization, but it is unclear which, if any, organizational process can enable it.

This leads to Figure 3, which depicts a ridge, or obstruction, that prevents knowledge from flowing quickly and powerfully from Points A to B as desired by the organization. Practically, the organization lacks a process for such quick and powerful knowledge to flow directly as delineated in Figure 2. Indeed, most organizations do lack such a process (Nissen, 2006a). Some other approach to sharing and applying the important IT acquisition knowledge is required.

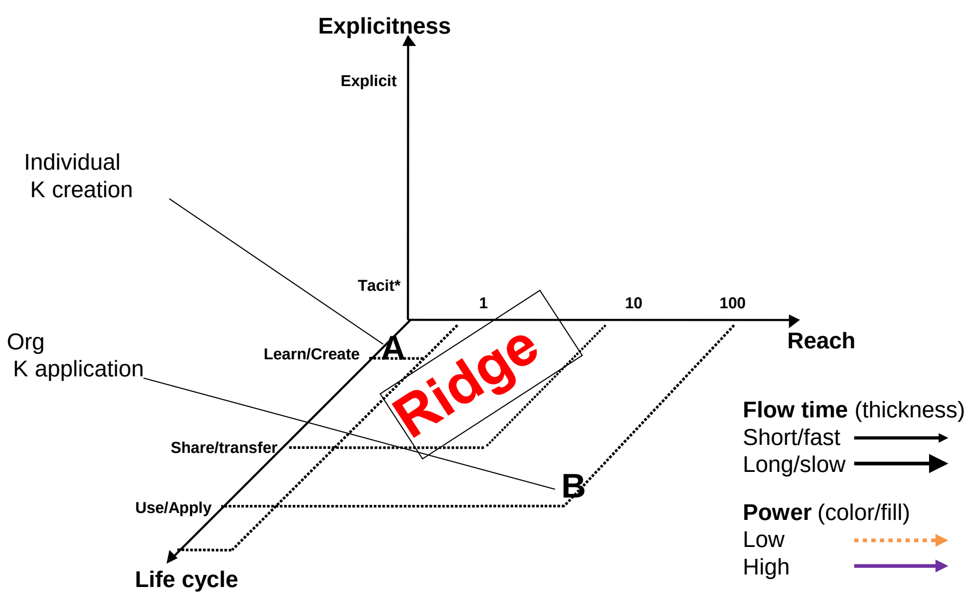

Figure 3. Knowledge Flow Obstruction

Figure 4 delineates two, alternate, archetypical knowledge flows corresponding to processes that are within this organization's capabilities. (We say *archetypical*, because most organizations employ these classic processes routinely, and because they present a vivid contrast in terms of how dynamic knowledge flows.) One knowledge flow is depicted in terms of a relatively fast (i.e., thin lines) but low-power (i.e., orange, dotted lines) vector series; this first flow is associated with explicit knowledge and utilizes one or more IS for knowledge articulation and distribution in explicit form. The other is delineated via a comparatively slow (i.e., thick lines) but high-power (i.e., purple, solid lines) vector; this second flow is associated with tacit knowledge and utilizes one or more human-centered approaches to knowledge sharing (e.g., group interaction, mentoring, personnel transfer).

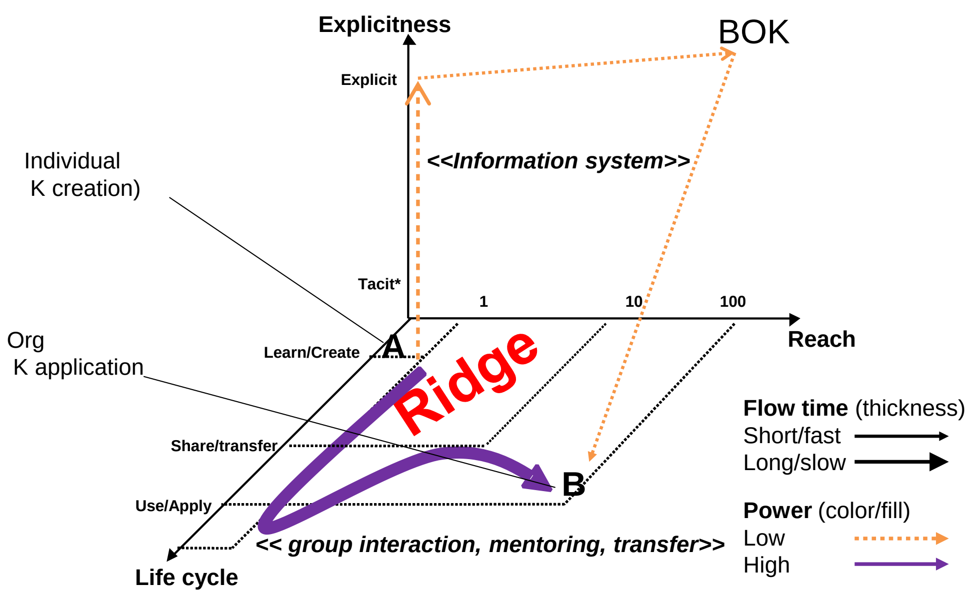

Figure 4. Alternate Archetypical Knowledge Flows

In some greater detail, the first knowledge flow consists of three vectors. The first vector is represented by a vertical line arising from Point A. This vector depicts the individual at Point A articulating his or her new, tacit knowledge via an IS so that it can be shared electronically. Such articulation (e.g., consider writing a procedure, developing a training course, posting to an intranet or social networking site) tends to be somewhat time-consuming, hence the relatively thick line. Articulating knowledge in explicit form also tends to dilute the knowledge in terms of power. Reading a book, for instance, about how to accomplish important acquisition tasks (e.g., contract negotiation, risk assessment, balancing program cost and schedule with performance) is not the same as having direct personal experience accomplishing those tasks; hence the orange, dotted line.

Once articulated in explicit form, however—particularly via IS—the knowledge can be shared very broadly (e.g., organization-wide) and very quickly (e.g., within seconds), albeit with diluted power; hence the thin, orange, dotted line at the top of the diagram. Indeed, one could consider this broad and fast flow as additive to the organization's express acquisition body of knowledge (BOK), which we note at the top-right of Figure 4. Such explicit BOK can then be accessed quickly and applied in turn by all 100 people in the organization. This articulated, explicit knowledge remains relatively diluted and less powerful, nonetheless, so application at Point B would not support the same performance level as at Point A; hence the thin, orange, dotted line descending down to Point B.

Alternatively, the second knowledge flow consists of a single vector, although it curves and bends through the tacit knowledge plane at the bottom of Figure 4. This vector depicts the individual at Point A applying his or her new, tacit knowledge and then sharing it with some number of other people (say, 10 people, as illustrated in Figure 4) through one or more techniques such as extended group interaction, mentoring, or personnel transfer to work directly with different coworkers across the organization.

Once each of these ten people has learned the new, tacit knowledge, then all of them can continue the process and share it using similar techniques (e.g., group interaction, mentoring, or personnel transfer) with others. Through such a process, 100 people (i.e., 10 people each sharing with another 10 people) can learn this new, tacit knowledge to the extent necessary for powerful application at Point B. This knowledge flow is depicted by a thick vector to indicate that it occurs comparatively slowly, but such vector is also delineated by a purple, solid line to show that the corresponding knowledge has high power and enables knowledge-based action at the same performance level as the individual who created it at Point A.

The key is, one can measure these five dimensions of knowledge—whether via explicit or tacit flows—and relate them to the corresponding knowledge-based process performance by people in the organization. Indeed, by correlating such dynamic knowledge measures with performance metrics, one can develop a model capable of analyzing, visualizing, and even predicting process performance based upon knowledge flow patterns.

Of course, many diverse combinations of these archetypical knowledge flows are possible too, yet most knowledge flows are likely to reflect some aspects of these two dynamic patterns (Nissen, 2006b). Through empirical analysis and calibration of specific knowledge flowing through any particular organization in the field, one can correlate 5D dynamic knowledge flows with work performance, resulting in a model capable of measurement and prediction. Through this technique, we are working to assess AWF quality in terms of dynamic knowledge flows.

III. Research Method

The first research question, articulated previously, includes a "how" interrogative and suggests that a qualitative method may be most appropriate to investigate it (Yin, 1994). Despite the generality of KFT and the 5D space described in the previous section, applying the corresponding analytic, visualization, and measurement techniques to assess AWF quality requires acquisition domain knowledge in general and process-specific understanding in particular. We need to study one or more specific acquisition processes in detail in order to apply the techniques and assess workforce quality. The case study method is highly appropriate for an investigation along these lines (Benbasat, Goldstein, & Mead, 1987; Eisenhardt & Graebner, 2007; Yin, 1994), and we conduct just such a case study in parallel with the investigation reported here.

The second research question, stated previously, also involves a "how" interrogative, and it likewise suggests a qualitative method. However, this second question calls for an extension of dynamic knowledge and performance measurement out to the tactical edges of warfare organizations, and hence is much more exploratory from an acquisition perspective. Because we seek an operational proxy for AWF quality, we investigate dynamic knowledge and performance through explicit examination of three warfare organizations and processes that are far removed from core acquisition.

One organization operates within a U.S. Navy fleet and has units deploying rhythmically to war zones and other areas overseas. A second organization operates within a Navy systems command but concentrates on ensuring the readiness of this same fleet. The third organization permeates functionally throughout naval operations and is responsible for information dominance. By interacting with knowledgeable representatives from each of these three organizations—and it is very important to note that these are warriors and other operational personnel, not acquisition professionals—we gain considerable insight into the key knowledge dynamics associated with warfare at the tactical edges.

Further, by triangulating between these three organizations, we identify a critical, knowledge-intensive process that can be represented with sufficient fidelity and granularity to suggest feasible application of our dynamic knowledge and performance measures. The process has the somewhat unwieldy name *Tasking, Collection, Processing, Exploitation, and Dissemination*, to which we refer simply by its acronym *TCPED*. In the results that follow, we delineate the TCPED process and seek to apply our dynamic knowledge and performance measures to it. We then attempt to interpret such application and to elucidate insight into assessing AWF quality via proxy.

IV. Results

Results from this exploratory investigation center on delineating the TCPED process, elaborating an insightful subprocess in detail, and applying our dynamic knowledge and performance measures to it. We discuss these in turn and then focus on elucidating insight into AWF quality.

A. TCPED

TCPED does not represent a new operational process per se, but with the U.S. Navy's relatively recent creation of its Information Dominance Corps, it has attracted considerable attention as a critical complement to the Find, Fix, Target, and Track (F2T2) process associated broadly with combat operations. The key F2T2 issue remains "knowledge — finding the targets" (Keeter, 2004), and as a knowledge-intensive process, TCPED addresses this issue directly, and hence represents a promising target of study.

Given the knowledge-intensive nature of TCPED, its execution is enabled fundamentally by IT, and IS are acquired routinely with the goal of enhancing warfare efficacy. This nature provides an excellent link back to our fundamental research question and interest in the AWF. From the operational perspective of TCPED participants at the tactical edges of organizations, IS acquired and fielded to enhance warfare efficacy should accomplish just that: enhance warfare efficacy. Further, such efficacy enhancement should be measurable.

The problem is, it is difficult to understand—much less measure—how well any particular warfare process is working, which of many different organizational arrangements are best across diverse missions, or how well various IS enhance or impede the process. Indeed, when seeking to acquire new IT and like technologies to enhance warfare efficacy, system implementation can make the operational processes *worse* in the battle space, and it is increasingly common for different acquired systems to fail in terms of interoperating (Nissen & Gallup, 2012).

Indeed, modern warfare efficacy requires a combination of people and technologies to enable warriors to leverage local knowledge and seize emergent opportunities to achieve commanders' intent across distributed organizations. This requirement highlights further the critical role played by TCPED, which seeks to enable commanders and warriors at the tactical edges to put dynamic knowledge into effective action, with or without IS in development or in the field.

Additionally, unlike many stable, mature, and well-understood warfare processes, TCPED remains in a constant state of analysis, refinement, and development. Hence, it represents a rapidly moving target for IT development, and engineering-oriented metrics used to evaluate most IS fail to address how dynamic knowledge translates into effective (or ineffective) action. Moreover, with current analytical models and metrics, it remains unclear how to assess whether any particular refinement in the warfare process, new IS implementation, or like change will lead to increased TCPED efficacy or whether performance will degrade instead. This lack of clarity illuminates a capacious gap between the efficiency of IT acquisition and the warfare efficacy of IS employment at the tactical edge.

Given the dynamic nature of the TCPED process, as characterized previously, we bound the scope of this exploratory project by concentrating on a particularly important and knowledge-centric subprocess: *exploitation*. Such bounding enables us to examine, within a single exploratory study, the feasibility of our approach to measuring the dynamic knowledge and performance of this operational process performed at the tactical edges of naval organizations. Follow-on researchers can then extend these promising results via subsequent studies through the process as a whole and, in turn, to other warfare processes seeking to benefit from IT acquisition.

B. TCPED Exploitation

Figure 5 delineates the principal tasks comprising TCPED exploitation. In this figure, process activities are depicted as rectangular boxes connected to one another via arrows to delineate the process workflow. Each process activity is situated within a horizontal region (e.g., referred to widely as *swim lanes*) that depicts the responsibility of a particular organizational group to accomplish it. For several instances, the leftmost process activities—"Correlate, Fuse Multi-Int Info" → "Operations Environment Impact" → "Evaluate Adversary" → "Develop Adversary COA"—are shown connected together as responsibilities of the "Assessor" group; the "Develop Adversary COA" activity interrelates with "Watch Analyst Coordination," the latter of which is shown as the responsibility of the Joint Intelligence Operations Center (JIOC), and which interrelates in turn with the Joint Operations Center (JOC) activity "Watch Coordination."

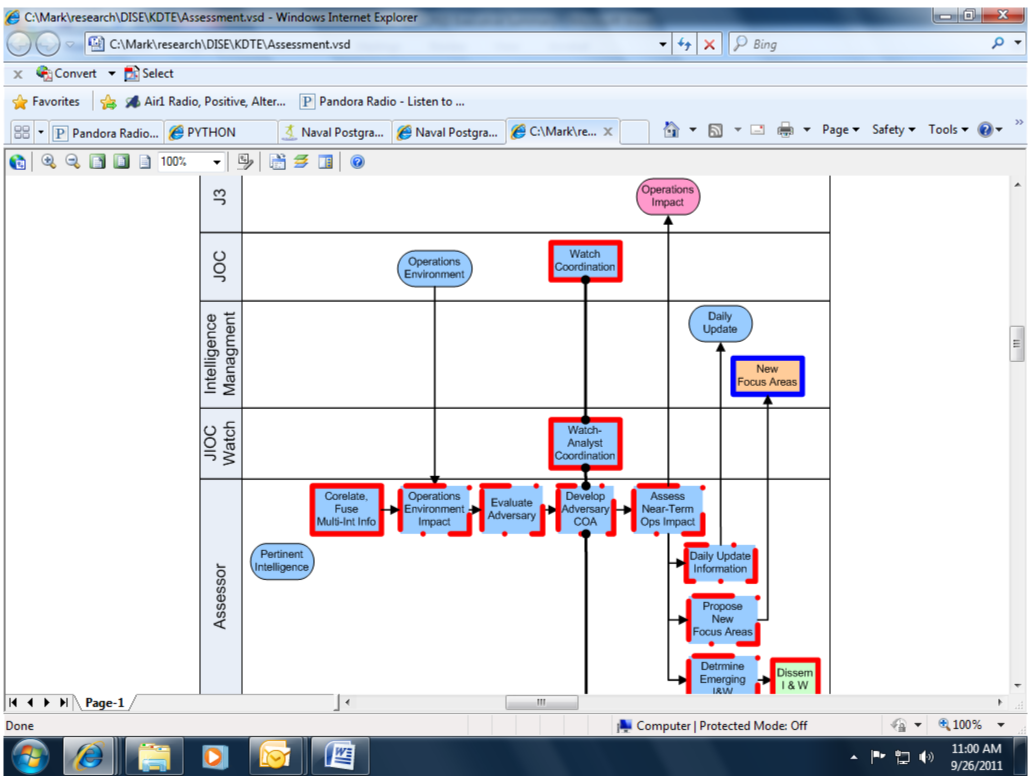

Figure 5. TCPED Exploitation Process Flow

Other instances pertain to "Assess Near-Term Ops Impact," the output of which activity provides important knowledge and information to Operations ("J3"); "Daily Update Information" and "Propose New Focus Areas," the output of which activities provide important knowledge and information to Intelligence Management;

and “Determine Emerging I&W” and “Dissem I&W,” both of which activities are performed by and are the responsibility of the Assessor as well. We omit graphical depiction or discussion of the other TCPED exploitation activities, because our intent is not to be exhaustive here, and these should suffice for our present purposes.

In particular, discussions with the knowledgeable people interviewed through this research indicate that the tasks labeled “Evaluate Adversary,” “Develop Adversary COA,” and “Assess Near-Term Ops Impact” are especially important and require considerable tacit knowledge. Recall that tacit knowledge, as powerful as it is, tends to flow relatively slowly and narrowly through organizations. This makes it particularly challenging to support via IT, and it provides an excellent focus for our exploration. Indeed, the people performing these activities must develop substantial, tacit knowledge pertaining to adversaries’ capabilities, likely actions, and their consequences in terms of friendly forces and operations. Such tasks also clearly require relevant and timely information, but knowledge of the adversary is key here, and the effectiveness of these tasks can contribute greatly to—or, if ineffective, impair instead—commanders’ decision-making and warriors’ actions on the tactical edge.

By focusing on how dynamic knowledge flows through warfare process activities such as these, and especially by linking the activities to knowledge-based actions enabled at the tactical edge, we can examine how well knowledge is flowing and supporting tactical action. Specifically, by integrating the organizations, personnel, and activities included in the exploitation process diagrammed in Figure 5 with key dimensions from KFT, we seek to identify critical paths in the process where knowledge is flowing well and appropriately, as well as identifying blocked paths where it is not, and we strive to use our dynamic knowledge and performance metrics to help overcome any disconnects between IT acquisition and warfare efficacy.

C. Dynamic Knowledge Flows

Through detailed analysis, we can delineate the principal knowledge flows enabling TCPED exploitation. Taking Develop Adversary COA as an express example, the people performing this activity rely fundamentally upon experience-based tacit knowledge (e.g., military tactics, adversary capabilities, organizational vulnerabilities). Although formal training courses, professional educational programs, and like approaches contribute to these knowledge flows, such knowledge is accumulated principally through direct experience (i.e., on-the-job training [OJT]), often over many years or even decades.

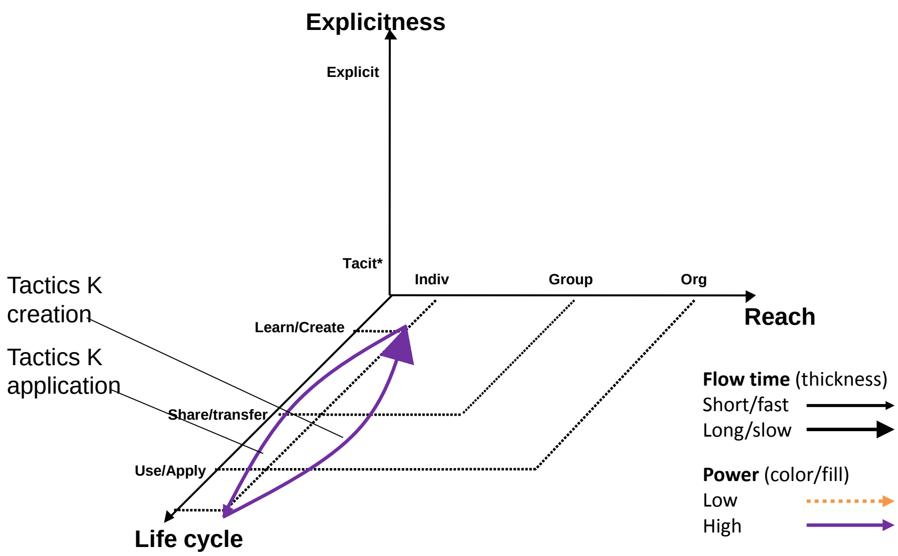

Figure 6. Military Tactics Knowledge Flows

Figure 6 delineates how military tactics knowledge, for instance, accumulates through cyclic iteration between applying one's existing tacit knowledge (labeled "Tactics K application" in the figure) and learning from the resulting experience (labeled "Tactics K creation" in the figure). We locate this cyclic knowledge flow vector at the individual level of reach, indicating that the Develop Adversary COA activity is conducted in this case by a single individual; were multiple people to engage jointly in assessments such as this, we would simply relocate the corresponding knowledge flows to the group level, with the same basic pattern persisting.

Consistent with our previous discussion, one can observe from Figure 6 how the vector for knowledge application is relatively thin, denoting that the flow is correspondingly fast, yet this vector is delineated via a purple, solid arrow, denoting that the flow reflects powerful, tacit knowledge; that is, once tacit knowledge has been acquired over time, it can be applied relatively quickly. In partial contrast, the complementary vector for knowledge creation is comparably thick, denoting that the knowledge acquisition flow is relatively slow, yet this vector is also delineated via a purple, solid arrow, similarly denoting that the flow reflects powerful, tacit knowledge.

Continuing with the Develop Adversary COA example, the people performing this activity also rely on a situated understanding of the organization's current mission-environment context, the adversary evaluation synthesized in the preceding exploitation process step, and contemporaneous knowledge regarding both current and future operations being conducted and planned, respectively, by the organization. Knowledge flowing to enable these process activities follows somewhat different patterns than those activities pertaining to military tactics. In particular, these latter knowledge flows involve interactions across different organizational groups, and they involve both tacit and explicit knowledge.

For instance, Figure 7 delineates three knowledge flows associated with tacit knowledge sharing and intergroup accumulation. The leftmost cyclic vector (labeled "Individual K accumulation") is comparable to that discussed previously in Figure 6, except that instead of military tactics knowledge, it pertains to the latter knowledge flows (e.g., associated with current mission-environment, adversary evaluation, and current and future operations). We continue to focus on individual knowledge accumulated by a single person—in this case, within the assessor group—but notice that we include a similar cyclic vector located at the intergroup level.

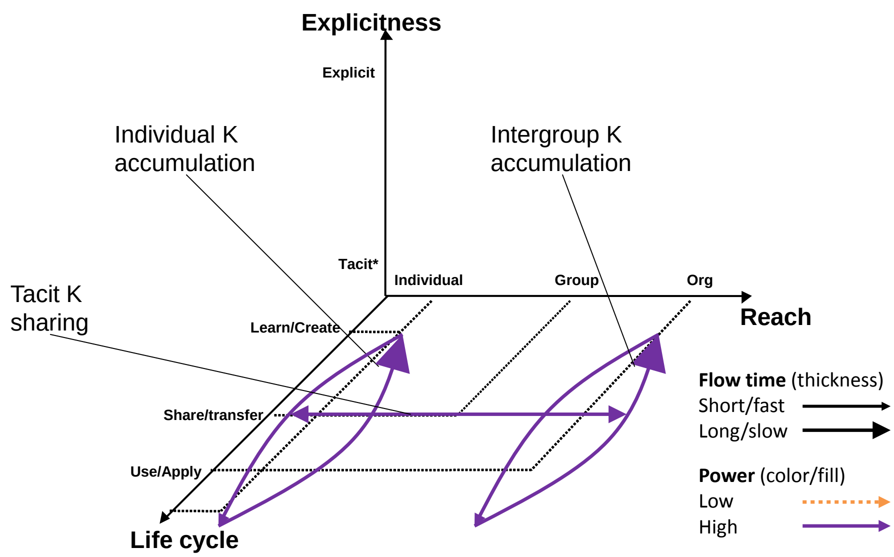

Figure 7. Tacit Knowledge Sharing & Intergroup Accumulation

This latter vector (labeled “Intergroup K accumulation”) reflects tacit knowledge accumulating across different organizational groups; multiple individuals from a variety of groups work and learn from their experiences together. The intergroup vector follows the same cyclic pattern as that seen with individual OJT, only at a higher organizational level. As with individual knowledge accumulation, this intergroup accumulation is delineated by a cyclic, purple, solid vector reflecting knowledge application and creation occurring at two different rates (i.e., quickly and slowly, respectively).

A third vector (labeled “Tacit K sharing”) links the other two. Such tacit knowledge sharing reflects individuals—who accumulate knowledge (especially via OJT) within their separate groups—sharing knowledge with people in other groups through conversation, dialogue, face-to-face (F2F) interaction, and like means. The two-headed arrow included with this sharing vector depicts knowledge flowing bi-directionally: individuals share knowledge across groups in the organization, and they also learn through this knowledge process.

As with the two cyclic vectors delineated and discussed previously, knowledge flows corresponding to such tacit sharing are depicted with a purple, solid vector to designate powerful tacit knowledge, and the vector is depicted with a relatively thick line to indicate that tacit knowledge flows across organizational groups tend to accumulate relatively slowly. However, we depict this sharing vector with a line that exhibits intermediate thickness; that is, the vector is thicker than the application vector lines—suggesting that tacit knowledge application flows across groups (e.g., in a matter of days, weeks, and months) more slowly than via individual application (e.g., in a matter of minutes, hours, and days)—but thinner than the creation vectors—suggesting that such cross-group knowledge can flow more quickly than can individual accumulation of experience-based tacit knowledge (e.g., in a matter of months, years, and decades).

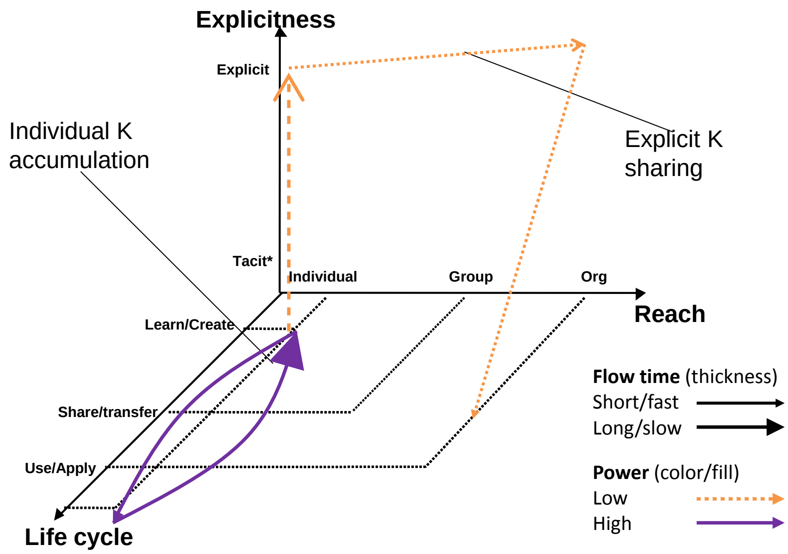

Figure 8. Explicit Organizational Knowledge Sharing

As another instance, Figure 8 delineates alternate knowledge flows associated with explicit organizational knowledge sharing. The leftmost cyclic vector (labeled "Individual K accumulation") is identical to that discussed previously in Figure 7 (e.g., cyclic, purple, solid, powerful, tacit). We continue to focus on individual knowledge accumulated by a single person—in this case, within the assessor group—but notice that we include a three-segment flow (labeled "Explicit K sharing") to depict knowledge being shared organization-wide in explicit form.

This three-segment flow begins with a vertical vector rising up out of the tacit plane, as an individual (i.e., in the assessor group) articulates his or her tacit knowledge into explicit form (e.g., via textual reports, graphical sketches, digital images). This articulation can be a time-consuming process; hence, the corresponding knowledge flow vector is depicted by a relatively thick line. In addition, we understand that such articulated, explicit knowledge does not reflect the same power level as the tacit knowledge used for its creation; hence, the corresponding knowledge flow vector is depicted by an orange, dotted line.

The second vector comprising this three segment flow begins where the first vector terminates. Once articulated in explicit form, such knowledge can be stored, replicated, and disseminated quickly and broadly via one or more IS (e.g., intranet document repositories, online sharing tools, common operational displays). This second vector in the segment is delineated by a thin line to denote fast knowledge flows, but the line remains orange and dotted to depict its diluted power. The third vector in the segment is also depicted by a thin, orange, dotted vector, which represents this same, diluted, explicit knowledge flowing via IS quickly and broadly across the organization.

D. Dynamic Knowledge and Performance Measurement

Through detailed analysis, we identify and operationalize three KFT metrics that appear to be particularly insightful for our present purposes: *knowledge reach* (i.e., how many people in the organization share specific chunks of knowledge),

knowledge flow time (i.e., how long it takes chunks of tacit and explicit knowledge to flow from where and when they are to where and when they're needed), and *knowledge power* (i.e., the performance level of knowledge-enabled work). Continuing with Develop Adversary COA as an express example, we can begin to quantify the key knowledge flows delineated previously.

Table 1. ROOM Knowledge Flow Measurement

Knowledge Flow	Reach	Flow Time	Power
Individual K Accumulation	1	Years	Very High
Intergroup K Accumulation	10	Months	High
Tacit K Sharing	10	Days	High
Explicit K Sharing	100	Hours	Diluted

For instance, Table 1 summarizes rough order of magnitude (ROOM), three-dimensional estimates for each of the four knowledge flows delineated and discussed previously with respect to the Develop Adversary COA activity within TCPED exploitation. In this table, we approximate knowledge flow measurements only to an order of magnitude, but we begin to illustrate the use and utility of the approach, and we outline a method for obtaining higher fidelity measurements in practice.

In the first column of the table, we list each of the four knowledge flows discussed previously, and in the other three columns, we summarize ROOM estimates for knowledge reach, flow time, and power. Looking first at individual knowledge accumulation, the reach is listed as 1; this reflects our previous discussion of knowledge being accumulated iteratively at the individual level, hence unitary reach. In the table, flow time is listed in order of magnitude as "years" for comparison with the other knowledge flows; this reflects our discussion about how deep, experience-based tacit knowledge (e.g., pertaining to military tactics) can require years or decades to accumulate. Power is listed likewise in order of magnitude as "very high" for similar comparison with the other knowledge flows; this estimate is somewhat definitional, but it reflects that experience-based tacit knowledge does not suffer from power dilution, and it is meant to reflect the considerable power of tacit knowledge accumulated over long periods of time and through abundant experience.

Looking next at intergroup knowledge accumulation, rough estimates for this knowledge flow indicate that 10 people can be reached by it; this is an order of magnitude larger than that shown for individual knowledge accumulation, and it reflects knowledge flowing to multiple people across organizational groups. The flow time estimated for intergroup knowledge flows is summarized as “months,” which is an order of magnitude faster than that for individual knowledge accumulation; this reflects the comparatively lower level of deep knowledge associated with intergroup knowledge and work flows, as people across groups interact principally via their present assignments—which, in this naval context, generally span less than a year. As discussed previously, the power level is listed simply as “high” to reflect that intergroup tacit knowledge (e.g., people learning to work well together across groups) does not suffer from power dilution, but it also reflects that the power level is not comparable to that associated with deep, experience-based knowledge accumulated over years of individual experience (e.g., pertaining to military tactics).

Estimates for the third knowledge flow (i.e., tacit knowledge sharing) are similar in terms of reach (10), but they reflect more than another order of magnitude reduction in flow time (i.e., “days”); this corresponds to the principle that knowledge sharing can be accomplished more quickly than the associated knowledge accumulation (Nissen, 2006b). The (“high”) power level matches that for intergroup accumulation mentioned previously and for the same reasons.

In considerable contrast, the flows associated with the fourth knowledge flow (i.e., explicit knowledge sharing) are quantitatively very different. We estimate the reach at 100 in the table, but the knowledge flows are constrained only by the reach of the network infrastructure; hence, this figure could be many orders of magnitude larger (e.g., consider a report, through which everyone in a 100,000 person organization has access to the same explicit knowledge). The estimate for flow time is similar in that we list it as "hours" (e.g., principally to account for the time required to articulate knowledge in explicit form), whereas once made explicit, such knowledge can be shared in seconds.

Moreover, the power level ("diluted") for this explicit knowledge flow is qualitatively different than that for its tacit counterparts; this is also somewhat definitional, but it indicates that most people reading written documents, for example, will not be expected to perform knowledge-based activities at the same level as the people writing those documents.

E. System Assessment

The remaining measurement of knowledge power is linked directly to performance of the work activities enabled by such knowledge. In the case of Develop Adversary COA, to continue our previous example, we could approach such measurement via multiple operationalizations. For several instances, we could track how much time is required to develop a set of adversary COAs sufficiently well for inclusion in a morning flag brief (i.e., appropriate for presentation to a flag officer); using the same flag brief criterion, we could count how many sufficiently credible adversary COAs are developed within a set time frame (e.g., one day, week, or month); we could ask the flag officer and staff in question (e.g., including the Chief of Staff and other directly reporting officers) to evaluate the quality of each adversary COA presented (e.g., based on criteria of importance to them); or we could pursue the development of other, likewise understandable and relevant performance measures. Any such performance measure can serve as a quantitative (and possibly multidimensional) proxy for knowledge power.

With one or more such measures in hand, we could then establish a baseline—comprised of quantitative measurements for *reach, flow time,* and *knowledge power/performance*—for the organization as it operates as usual. To evaluate some particular IS, we could simply compare this baseline with measurements taken as the organization uses the IS under controlled, or at least comparable, conditions. For instance, say that we wish to test a prototype IS designed to improve tacit knowledge sharing through introduction of social media techniques; we could measure the knowledge flows both with and without such IS to assess its impacts.

Specifically, using one or more proxy measures as suggested previously (e.g., *time required to develop a set of adversary COAs for a flag brief, how many adversary COAs are developed, flag officer quality evaluation*, others), we could conduct an experiment in the laboratory or in the “field” (e.g., on deployed ships at sea) and measure knowledge and performance directly. As an experiment to compare performance with and without the prototype IS, for instance, we would ideally like to see the same people, performing the same tasks, in the same environments and settings, at the same times of day, seasons of year, weather conditions, sea states, and other factors to isolate use of that IS as the only difference. In other words, one set of dynamic knowledge measurements would be taken for performance in the baseline situation; a second set of measurements would be taken for performance with a prototype IS; and, ideally (e.g., with good experiment design and techniques), the difference would represent solely the effect of that IS.

With these measurements in hand, the difference in task performance becomes an operational measure of IS efficacy; that is, if the only difference between experiment cases is whether the prototype IS is used or not, and task performance is measurably better or worse in one case or the other, then we have a knowledge-based assessment of how well such IS improves (or worsens) work performance at the tactical edge of the organization (e.g., TCPED exploitation). Moreover, in addition to using traditional, engineering-oriented performance measures (e.g., bandwidth, technical reliability, memory), this assessment can be employed to evaluate the IS operationally—and under controlled conditions—not just technically. The potential is huge.

Further, given sufficient experience with conducting experiments along these lines, this approach can even be used to *specify* new IT and other systems to be acquired; that is, in conjunction with using only engineering measures of IS performance, for instance, the acquisition organization can specify *improvement in operational task performance* as a key criterion for evaluation. This way, acquisition personnel can conduct efficient system acquisitions, and warriors on the tactical edges of organizations can use systems that improve their work performance. We bridge the gap between acquirer and warrior, and everybody wins.

F. Illustrative Example

In this section, we include an illustrative example of application to an hypothetical IT system competition. We use only representative values for illustration here, but the approach and associated techniques can be applied directly to system competitions in the field. For continuity, we continue with the Develop Adversary COA task discussed previously, and we build upon the rough knowledge flows and measurements reported previously.

Table 2. Baseline Knowledge Flow Measurement

Knowledge Flow	Reach	Flow Time	Power	X-Power
Tacit K Sharing	10	20 Hours	95%	9.5
Explicit K Sharing	100	2 Hours	5%	5.0

Table 2 recapitulates the most relevant measurements reported in Table 1 for what we term the baseline, representing the Develop Adversary COA task as it is performed today (i.e., sans new IS); that is, the baseline measurements are used for comparison with this same task performed with the support of two competing IS prototypes: (1) a social media application designed to improve tacit knowledge sharing, versus (2) a document collaboration application designed to improve explicit knowledge sharing.

Notice in Table 2 that we limit our summary to the pair of knowledge flows associated directly with the alternate IS: tacit knowledge sharing (addressed by IS-1) and explicit knowledge sharing (addressed by IS-2). Recall, from our discussion above, that the knowledge flow corresponding to tacit knowledge sharing reflects individuals—who accumulate knowledge (especially via OJT) within their separate groups—sharing knowledge with people in other groups through conversation, dialogue, F2F interaction, and like means. The central idea of IS-1 is to enable such knowledge sharing remotely; that is, the IS intends to enable and promote tacit knowledge sharing without the need for (as much) F2F interaction.

Recall, further from our discussion above, that the knowledge flow corresponding to explicit knowledge sharing reflects organizational artifacts (e.g., textual reports, graphical sketches, digital images, and like media) that are stored, replicated, and disseminated quickly and broadly via intranet document repositories, online sharing applications, common operational displays, and like tools. The central idea of IS-2 is to enable recipients of assessor reports (e.g., in the JIOC and JOC groups) to interact with assessors during report development; that is, the IS intends to enhance and accelerate explicit knowledge sharing by providing recipients with access to assessor draft reports and to enable communication before finished reports are released officially.

Notice also that we replace the ROOM estimates from Table 1 with quantitative values. For instance, the “days” flow time estimate from above for the tacit knowledge sharing flow reads as “20 hours” in Table 2. Based on observation and discussion, roughly 20 hours are required for key tacit knowledge to complete its flows. Further, the “high” power estimate from above reads as “95%” here. As such, 10 different people outside the assessor group (e.g., in the JIOC and JOC) are able to explain the details of each adversary COA from memory with 95% accuracy on average; the other way to look at this is that 19 of 20 people can explain the details with 100% accuracy.

Similarly, the “hours” flow time estimate from above for the explicit knowledge sharing flow reads as “2 hours” here. This indicates that roughly 2 hours are required for a high-quality and credible adversary COA to be articulated, shared with, and understood by recipients. Further, the “diluted” power estimate from above reads as 5% here. As such, 100 different people outside the assessor group (e.g., in the JIOC and JOC) are able to explain the details of each adversary COA from memory with 5% accuracy on average; the other way to look at this is that five of 100 people can explain the details with 100% accuracy.

Notice finally that we include a fifth column in Table 2 (labeled “X-Power”) to represent the induced dimension *extended knowledge power*. Extended knowledge power is calculated as the product of knowledge reach and power levels; it reflects the combined distribution and efficacy of knowledge flows. For instance, the extended knowledge power for the tacit knowledge sharing flow is shown in the Table as 9.5 (i.e., reach of 10 [times] power of .95 = x-power of 9.5), whereas the value calculated for explicit knowledge sharing flow is shown as 5.0 (i.e., reach of 100 [times] power of .05 = x-power of 5.0).

This respective induction and quantification of the extended knowledge power dimension and measure provide us with a technique for comparing the efficacy of tacit and explicit knowledge flows directly, despite the significant differences between their dynamic characteristics and behaviors (e.g., quick, broad, diluted explicit flows versus slow, narrow, powerful tacit flows). Clearly, higher values are preferred over lower ones, but organizations face trade-offs regarding whether to emphasize explicit or tacit knowledge flows.

Table 3. IS Supported Knowledge Flow Measurement

Knowledge Flow	Reach	Flow Time	Power	X-Power
Tacit K Sharing (IS-1)	20	20 Hours	75%	15.0
Explicit K Sharing (IS-2)	20	2 Hours	10%	2.0

For further illustration, Table 3 summarizes these same knowledge flow measurements—for the same people, organizations, tasks, and time frames—after the prototype IS have been implemented and trained with. This point is important;

one cannot expect a new IS to be used effectively and productively before its users have been trained adequately. (It's humorous, nonetheless, how often one sees comparisons made without adequate training, particularly in field experiments.)

In the case of tacit knowledge sharing supported by IS-1, say that the social media application enables twice as many people to participate in the conversations (i.e., reach extends to 20) within the same 20-hour time frame (e.g., by obviating the need for collocation), but the power level decreases to 75% (e.g., due to losses via mobile social media applications). Despite the drop in power, the extended reach would more than make up for the loss, because of the extended power increase to 15.0. Alternatively, in the case of explicit knowledge sharing supported by IS-2, say that the document-sharing application reduces to 20 the number of people who can participate effectively within the same two-hour time frame (e.g., due to interference by multiple people interacting with the same documents), yet the power level of those who do participate increases to 10% (e.g., stemming from increased textual interaction across organizational groups). Despite the increase in power, the reduced reach would more than offset the gain, because of the extended power decrease to 2.0.

Table 4. Comparative Knowledge Flow Measurement

Knowledge Flow	**Baseline** (X-Power)	**IS Enabled** (X-Power)	**Difference** (X-Power)	**Difference** (Percentage)
Tacit K Sharing	9.5	15.0	+ 5.5	+ 58%
Explicit K Sharing	5.0	2.0	- 3.0	- 60%

In Table 4, we summarize the comparative results via four measurements. First, the Baseline X-Power contrast between the tacit and explicit knowledge sharing processes reflects our result from Table 2 (i.e., 9.5 versus 5.0, respectively). Second, the IS Enabled X-Power contrast between these same processes reflects similarly our result from Table 3 (i.e., 15.0 versus 2.0, respectively). Third, the Difference X-Power contrast measures the effect of incorporating the two IS. For instance, using IS-1 to support tacit knowledge sharing increases extended knowledge power by 5.5 (i.e., 15.0 – 9.5 = +5.5) for a 58% gain. In contrast, using IS-2 to support explicit knowledge sharing decreases extended power by 3.0 (i.e., 2.0 – 5.0 = -3.0) for a 60% loss.

Recall that the knowledge power measurement relates directly to organizational performance at the tactical edge, on the Develop Adversary COA task in this illustrative case. In addition to providing an objective and quantitative approach to assessing the potential value (or harm) of an IS of interest, the technique described in this report also suggests a way to specify performance requirements for candidate IS of interest.

Consider, for instance, if—in addition to whatever engineering specifications are desirable or customary—the specification read along the lines of, “the IS must demonstrate at least a 25% increase in X-Power measured during a fleet experimentation exercise.” This specification would arguably place considerable contractor emphasis on improving knowledge flow and work performance of users at the tactical edges of the warfare organizations targeted for the acquisition and implementation of their IS. It would also appear likely to help bridge the gap between acquisition efficiency and warfare efficacy.

V. Conclusion

The efficacy of defense acquisition is highly dependent upon acquisition workforce (AWF) quality, but assessing such quality remains a major challenge, particularly given the knowledge-intensive and dynamic nature of acquisition organizations and processes. Hence, it is difficult to gauge—much less predict—the impact of leadership interventions in terms of policy, process, regulation, organization, education, training, or like approaches.

Building upon the development and application of Knowledge Flow Theory over the past couple of decades, we have developed a state-of-the-art approach that enables us to analyze, visualize, and measure dynamic knowledge and performance. The main idea is to apply this approach inwardly to measure the dynamic knowledge and performance of acquisition processes (e.g., within contracting and project management organizations), but we also look outwardly (e.g., at warfare processes at the tactical edges of military combat organizations) to conceptualize an operational proxy for acquisition workforce quality: *end customer performance*. This proxy offers its best potential to complement, not replace, other metrics in use, development, and conceptualization today, but it arguably concentrates on one of the most important AWF quality determinants: how acquired systems affect operational performance.

In this exploratory study, we examine fast-changing IS acquisition from the perspective of warfare at the tactical edge, and we consider dynamic knowledge and performance measures to both complement and contrast with extant, engineering-oriented metrics used to specify and assess most acquired systems today. In particular, we examine TCPED and concentrate our attention on the exploitation process. Analysis enables us to delineate the key process activities, roles, relationships, and responsible organizations, and we leverage such delineation to assess, visualize, and measure the corresponding dynamic knowledge and performance.

Concentrating still further on the exploitation process activity Develop Adversary COA, we step through an example of how our approach can be used to assess dynamic knowledge and performance on the tactical edges of warfare organizations involved with TCPED. We focus especially on how such assessment can be employed to evaluate one or more IS being considered for acquisition and possible integration.

This TCPED example includes delineation of four key knowledge flows associated with adversary COA development (i.e., military tactics knowledge development, intergroup knowledge accumulation, tacit knowledge sharing, explicit knowledge sharing) and rough estimation of the knowledge reach, flow time, and power corresponding to each. We take initial measurements for the process activities with no support from an IS under consideration. This becomes our baseline for comparison. Then we take measurements from the same process activities with support from one particular IS (e.g., IS-1), then from another (e.g., IS-2), to establish a measurement basis for comparison and evaluation. If acquisition evaluators are able to control the assessments sufficiently well (especially via laboratory or field experiment), then one can ascribe any performance differences solely to the IS. This ascription would help to bridge the capacious gap between acquisition efficiency and warfare efficacy on the tactical edges of organizations.

In turn, we provide a practical illustration of the approach, through which we examine two competing prototype IS conceptualized for elaboration, and we elucidate the kinds of insights that can emerge through assessment, visualization, and measurement of dynamic knowledge flows. Specifically, we illustrate via example how one particular IS (i.e., IS-1, which is conceived to enhance tacit knowledge sharing via social media applications) seeks to enhance performance through emphasis on tacit knowledge flows and how a competing IS (i.e., IS-2, which is conceived to enhance explicit knowledge sharing via document collaboration applications) seeks to enhance performance instead through emphasis on explicit knowledge flows. We further extend our set of knowledge and performance measures to induce the new dimension *extended knowledge power*, which combines knowledge reach and power together into a single metric.

Results of our study illustrate how process performance can either improve or degrade when a particular IS is introduced into a process, and they articulate how the kinds of dynamic knowledge and performance measures discussed in this report can elucidate a critical aspect of IS for evaluation: how acquired systems affect operational performance. Indeed, through this practical illustration, we find one IS increasing process performance by 58%, whereas the competing IS effects a 60% performance decrease.

Building upon these results, one can now apply the approach described in this report to any number of IS acquisitions and use *end customer performance* as an objective measure of IS efficacy. This application will require some venue for (at least partially controlled) experimentation (e.g., in the laboratory, via field experiments, phased or blocked implementation), but the potential benefit is huge. Moreover, in addition to using dynamic knowledge and process measurement as illustrated here for evaluation, one can leverage the same set of measures to specify IS in the conceptualization, design, and development phases. Essentially, *end customer performance* becomes an objective design consideration through this revolutionary approach.

In terms of measuring AWF quality, this research establishes stronger and more direct linkages between what acquisition personnel know (especially focused internally on acquisition organizations and processes) and what warriors on the tactical edges of organizations need (especially IS that improve warfare efficacy), and it provides a set of dynamic knowledge and performance measures that can be used to bridge the gap between acquisition efficiency and warfare efficacy. This measurement step alone offers potential to improve the effectiveness of those acquisition people and organizations that implement the approach described in this report; hence, one new measure of AWF quality emerges directly: *use of dynamic* *knowledge and process measures to assess end customer efficacy*. In other words, the working hypothesis is that those acquisition people and organizations that use this approach will be more effective than those that do not; hence, simply assessing the extent to which this approach is used may become an important, complementary measure of AWF quality.

Further, results from this research suggest that personnel in the AWF may benefit from increased understanding of the end customers for whom they acquire information and other systems. The acquisition system as a whole provides program offices, liaisons, needs determination and justification steps, milestone and oversight authorities, operational testing and evaluation, and myriad other steps seeking to represent end customers. Nonetheless, there may be no substitute for acquisition personnel who understand their customers in considerable detail.

These results do not suggest that procurement clerks should be outfitted with helmets, rifles, and boots and then sent to the tactical edges of warfare organizations, or that warriors on such tactical edges should be given procurement assignments; rather, it suggests that by examining the key warfare processes performed at the tactical edges—and in particular, understanding the most important dynamic knowledge and performance characteristics of such processes—even procurement clerks in offices half a world away may gain important insight into their end customers—insight that may lead to improved workforce quality and that can be measured.

As with any investigation, the exploratory research described in this report has limitations. Indeed, its very exploratory nature limits the magnitude and scope of what can be accomplished through a single study or articulated through a single technical report, and the relatively high level of our TCPED examination lacks much of the detail that a more ambitious follow-on study could provide. The nature of our practical illustration represents another limitation, because we use hypothetical IS and representative performance estimates to elaborate the approach; hence, a more detailed examination of one or more operational processes in the field, along with evaluation of one or more implemented prototype IS for comparison, would provide powerful information regarding the relative performance of such IS. This represents another promising topic for follow-up research.

We also note the potential issues with comparing knowledge power across dramatically different knowledge flow processes and the need to understand our set of measures more clearly. In our practical illustration, for instance, we examine two knowledge flow processes associated with the same TCPED exploitation activity and focus on the same dynamics: knowledge sharing in support of adversary COA development. In this case, both competing IS (i.e., based on social media applications versus document collaboration applications) could be viewed as either complementary or supplementary artifacts, but such artifact complementation or supplementation may not always be feasible in terms of practical application; hence, the limits of this approach require further investigation.

Moreover, the dynamic knowledge and performance measures themselves (e.g., *knowledge reach, flow time, power, extended power*) require improved understanding. For instance, can each of these measures support quantification and analysis via ratio scales, as implied in this report, or will analysts have to settle for interval, ordinal, or possibly even nominal scales for evaluation? As another instance, can each of these measures be defined and operationalized objectively and without the need for interpretation, or will they be more situated and context-dependent? How will instruments to obtain such measurements be validated, and how reliable will such instruments be across different organization domains, process classes, IS types, and people taking measurements? There are other limitations, of course, but the results are sufficiently promising to merit future research along the lines of this investigation, particularly as noted in this section.

There is much to be done, and in our present environment of intense budget austerity, the need to work now is evident. This kind of research requires support, however. One cannot expect for warriors fighting at the tactical edges of combat organizations to conduct controlled experiments; likewise, most acquisition professionals have neither the time nor the expertise to do so. Instead, the work needed now requires professional researchers to do what they do best: conduct research to develop new knowledge that can be applied and leveraged to help the warrior and acquisition professional alike.

This requires funding, of course—funding that many will find difficult to prioritize over funds intended for warfare, procurement, and similar pressing needs. But applied research along the lines of this investigation can exert enormous leverage. If even a small study such as this can develop a technique that improves an organization spending hundreds of billions of dollars a year by only a tiny bit—say, one one-hundredth of one percent—that amounts to tens of millions of dollars per year in savings! Given that small studies correspond to costs in the thousands—yet have the potential to save tens of millions—they appear to be compelling investments, even in tough economic and budgetary times.

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- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

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