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The New Global Information Economy: Implications and Recommendations for Service-Oriented Architectures (SOAs)

Topic: Edge Organizations

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The New Global Information Economy

Implications and Recommendations for Service-Oriented Architectures (SOAs)

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Abstract: *Service-oriented architecture (SOA), a term often used today in conjunction with net-centric operations, implies that existing and future DoD information capabilities will be engineered to publish product and/or service offerings within a strategic context that allows virtually all employees and applications to readily discover and use them. SOA principles are essential to transforming traditional system-centric Defense organizations into Information Age activities that are net-centric, architecturally agile, and otherwise responsive to fast changing mission and business needs. The large-scale service-oriented architectures that DoD planners envision are designed to lower barriers to dynamic information sharing and improve content quality, quantity and propriety by leveraging the power of self-organization, self-synchronization and market forces. For these reasons, SOAs promise to help organizations deliver unprecedented value to their customers. In this paper we review a few key concepts of service-oriented architectures as fundamental enablers of "net-centricity." We then examine the implications for SOAs in the new DoD global information economy and offer a few key recommendations.*

Keywords: complex systems theory, enterprise architecture, global information economy, global information grid, information economy, information market, net-centric architecture, service-oriented architecture, self-organization, self-synchronization, scale-free networks.

1 Introduction

Widespread information sharing and ease of collaboration are the hallmarks of net-centric operations as envisioned by Department of Defense (DoD) planners. Net-centric operations are an enabler of both speed and precision in decision-making and in military operations. From maneuver units on the urban battlefield, to ships at sea, from air and space sensor platforms to large-scale command and intelligence centers, increasingly capable Defense intranets are fostering a complex global information economy.

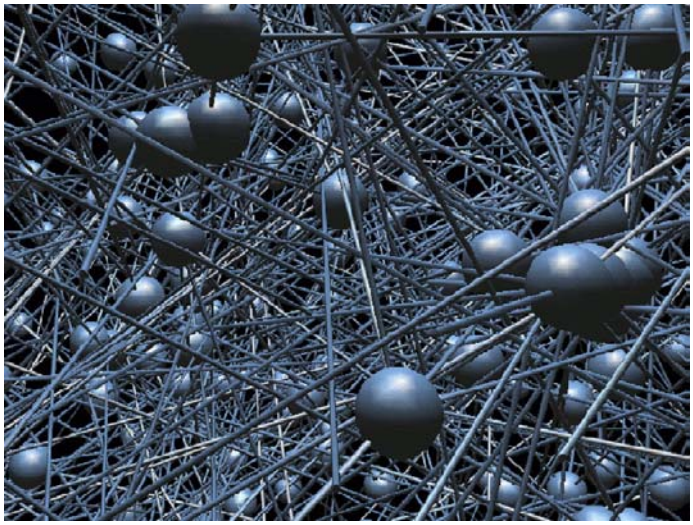

Fig. 1. A Modern Graphical Illustration of Complex Networks

This growing complexity, notionally illustrated in Fig. 1, is so phenomenal that experts[i,ii,iii1] have turned to complex systems theory for help in understanding the behavioral characteristics and emergent properties of inter-networked capabilities. From an information sharing perspective, producers and consumers of interchangeable and easily orchestrated information services may be both organizationally and geographically independent and interdependent. These distributed cooperating autonomous large-

[1] In particular, reference *iii* provides an in-depth survey of a wide body of appropriate literature on complex systems theory.

grain software services can be readily located and invoked by all authorized participants.[iv]

In the DoD, the term "net-centricity" is used in conjunction with the concept of service-oriented architectures (SOA). Net-centric architecture and the emerging information management transformation in the DoD has been envisioned as a path forward toward moving away from traditional family-of-systems (FoS) modernization efforts toward an information sharing-based approach to dynamic, collaborative interactions.

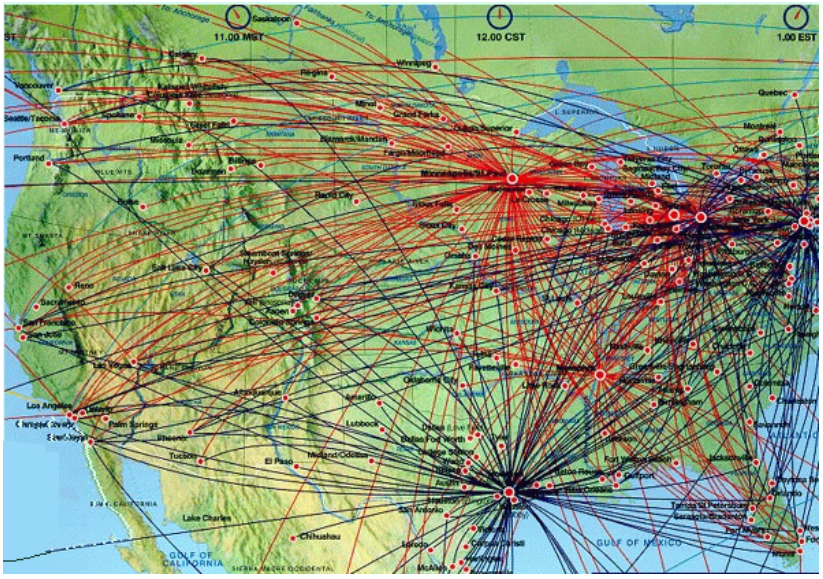

Fig. 2. Air Transportation Routes and Hubs

To visualize net-centric architecture, it helps to have a mental picture of a network of cities as "hubs of information capabilities," that evolved into a scale-free network[2]. These cities, illustrated in Fig. 2 as hubs of capabilities, are linked by various "lines of communications" (air, land, sea, and information lines of communications). Within this context, capability sharing and the new global economy centered on cities is a compelling, easy to understand metaphor for the net-centric concepts of information

[2] A more detailed discussion on scale-free networks may be found in sections 3 and 4 of this paper.

sharing and the global information economy that are the focus of this work. It is easy for most people visualize the "cities metaphor" making the metaphor a good one to build upon in this paper.

Net-centric concepts are often examined in terms of biological models and complex systems theory. The "cities metaphor" (as information-centric capabilities and services) appears to be an appropriate metaphor for the vast majority of the DoD community working to achieve the transformation objectives of the nation's leadership. Another reason the "cities metaphor" for net-centric architecture "works" is that anyone who has flown in an airplane and opened the airlines travel magazine to the colorful map of the US (and often the world), with an attractive overlay of the airline's air transportation hubs and routes, can easily relate the network of cities to the net-centric concepts we offer in this paper.

The airlines, for all practical purposes, do not "integrate" the cities. Nor do the airlines expend resources decomposing "cities" into smaller "neighborhoods." The airlines (and other intercity transportation services) provide services to move people, cargo, and mail between the cities. The same analogy applies to information technology systems, services and capabilities. Net-centric architecture does not strive to integrate nor decompose "the cities." Net-centric architecture provides basic information services to move information between "the cities." This is one reason why emerging net-centric architectures are often referred to in conjunction with the concepts of service-oriented architectures.

In the context of net-centric architecture, every participant in the information economy (all "city dwellers," so to speak) is both a producer and a consumer of information. Net-centric architecture, in effect, creates a vast boundless information economy unconstrained by hierarchical organizational boundaries and the constraints of the underlying technology life cycles.[v] Just as cities, once isolated centers of social and economic activities, become "connected" by various modes of transportation, information systems are connected by net-centric services, such as discovery services, search services "intercity" message services, and other information sharing capabilities.

The new DoD global information economy becomes, like other economic systems, a highly agile and adaptive global information marketplace that enables the dynamic organization of capabilities, relationships and services. These "meta-capabilities" facilitate, in near real-time, our desired military effects and outcomes.

In this discussion paper, we will continue the development of net-centric architectural implications of service-oriented architecture. We begin by discussing service-oriented architectures in the context of net-centric architectures in the DoD. We then provide additional background and supporting information on the global information economy and the application of complex systems theory to the discussion. Finally, we offer a few beginning net-centric architectural recommendations based on the concepts and implications developed in the paper.

2 SOA and Net-Centricity in the DoD

All indications are that we will be increasingly required to rapidly reorganize and respond to changing missions scenarios. The ability to rapidly adapt, reorganize capabilities, and quickly respond to events when "the fight is on" and in "the fog of war" is a reality of modern day warfare. The DoD mission is dynamically shaped by continually changing threats, our own operational success, the political realities of life in a democratic society, and myriad other completely unpredictable future events. For these reasons and more, the DoD is evolving to leverage the vast power of information networks to enable rapid information sharing to foster agile, effects-based military operations.

One of the goals of net-centric architectures, and the underlying information transformation enabled by service-oriented architectures, is to evolve traditional compartmentalized and hierarchical military, business and intelligence systems into agile information sharing capabilities. Net-centric architecture is, therefore, rooted in the desire to evolve the US military beyond

organizational and technology-dependent, system-centric boundaries, toward a service-based approach to information sharing capabilities. This transformation is characterized by reducing the decision cycle, increasing the speed of organization, increasing speed of action, and operational precision, and at the same time, minimizing losses while achieving overwhelming victory.

Building upon our "cities analogy," service-oriented architectures may be viewed as communities (cities) that exist as information producers and consumers. These communities more-than-likely self-organized, for numerous practical reasons, and have myriad information-based capabilities that must be made available to other communities. For net-centric architectures to work effectively, all information capabilities must be connected to the network, searchable, discoverable, accessible and usable. Just as our industrial economy is strengthened by robust intercity trade, the information economy, and indeed our national security, is strengthened by robust "intercity" information sharing. Therefore, the information economy is very similar to the industrial economy.

The World Wide Web Consortium (W3C)[vi] defines service-oriented architecture (SOA) as *"a set of components which can be invoked, and whose interface descriptions can be published and discovered."* This definition, illustrated in Fig. 3, describes a group of software services that may easily share information because the services share a set of common semantics. These services are modularly implemented coarse-grain[3] information-based components that can be invoked by both information producers and consumers. The interface to these information services should be easily identified and invoked without direct knowledge of the internal organization and technical specifications of the service.

Service consumers and providers exist in each of our "cities." The challenge, in the net-centric information economy, is how to rapidly discover, broker and orchestrate services as information capabilities. In today's military, as in the industrial marketplace, there are very few technical barriers to entry into an information marketplace.

[3] "*Authorize and validate credit card transaction*" or *"provide coordinates of military significant movements in the AOR"* are examples of coarse-grain business/mission services.

Advances in the Internet over the past ten years have significantly lowered the cost-to-share information in the new global information economy.

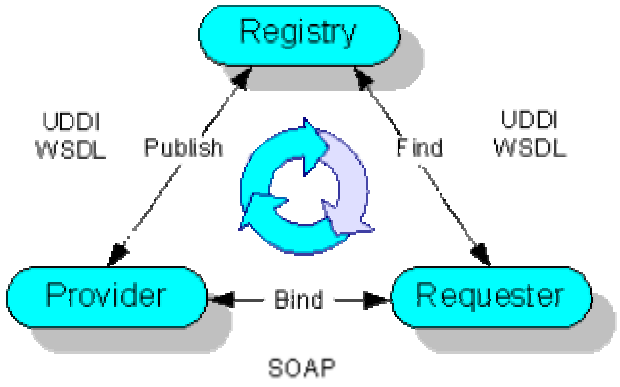

Fig. 3. The W3C Model of the SOA Concept

From a net-centric architectural perspective, administrators of information capabilities in a globally interconnected world are evolving their thinking to view themselves much like a metropolitan chamber of commerce would view their industrial capabilities, as a part of an evolving global information economy. Service contracts, also illustrated in Fig. 3, should be designed to be coarse-grained where the business interactions are characterized by best-of-breed market forces. There is not so much a single "enterprise perspective," but a global economic perspective. Information systems, modeled as information capabilities, become information services. They are like the cities on our colorful map; and the new global information economy becomes an abstraction of the totality of information sharing relationships and service contracts.

From a systems architecture perspective most, if not all, DoD systems could evolve to participate in the new DoD global information economy. DoD information system operators, however, must describe their information capabilities much like chambers of commerce describes their business capabilities.[4] An unpredictable and certain barrage of future technology platforms and "best of

[4] We offer the reader that it may soon be the right time to for the DoD to revisit the term "global information grid" in the context of the "new global information economy" as our military information services and capabilities evolve to become adaptive and responsive to change.

breed" vendor solutions insure that "the cites" will be constantly evolving. We must avoid the constraints of thinking about our own city and life in it—the functional stovepipe. We must think about capabilities we can offer to the global information community and capabilities we can draw from that community—in the final analysis dynamically organized resources to reduce cycle time, defects, and achieve unprecedented results. Whether it is speed, precision and overwhelming victory in combat or better faster, cheaper citizen services, it is all enabled by net-centric thinking—the global information economy and service-oriented architectural concepts.

This "new global information economy" implies that our DoD information capabilities must be organized as "cities" without the need to dictate to "the mayors" of our cities how their planners operate their information communities and services. Information services, from a global economic perspective, should be agnostic to local architectural governance. Therefore, to facilitate the DoD transition to a capabilities-based information economy, we must advance the notion of low-cost, rapid "intercity" information sharing. This model is supported by advances in the application of complex systems theory as applied to information networks, discussed in the next section.

To summarize, service-oriented architectures in the net-centric environment supports the transformation from traditional compartmentalized organizational and system-centric information technology systems to a global information economy of shared information services. The "cities metaphor" helps us evolve our thinking from an intractable "enterprise integration perspective" to a global information economic perspective, based on the practical realities of the world we live in and how we operate in our world. In the next section we briefly summarize a few supporting ideas from complex system theory. The background concepts help us understand the overall complexity, interdependence and emergent properties of the global information economy.

3 A Brief Review of Complex Systems Theory

Net-centric architectural concepts can be difficult to grasp when viewed as an interdependent global information economy. Contrast this interconnected view of information to the traditional compartmentalized approach to information technology and systems management. One of the many reasons that the concept of a global information economy is so intimidating is because many people are uncomfortable with the notion of an information economy that cannot be centrally managed nor controlled. Traditional structured architectural approaches fall short of the task and a new construct, or way of thinking, is required.

For this reason, more and more experts are looking to complex systems theory to help us understand the implications of information sharing in the new global information economy. Contrast the emerging global information economy with the vertically integrated military-industrial complex of thirty and forty years ago. Today's new global information economy is divided into myriad autonomous and interdependent "cities" producing and consuming specialized information products and services. The levels and degrees of interactions between information service providers in the net-centric environment is vast, complex and appears to be growing almost exponentially.

In fact, the desired strength and robustness of the global information economy mandates a new way of thinking. The global information economy consists of hundreds, maybe thousands, of autonomous and interdependent information capabilities, just like the "cities" in our visual analogy. Information capabilities, links, and inter-relationships appears to be increasing exponentially as the information economy transforms the DoD from the management of internal systems and platforms, to the management and orchestration of vast global information capabilities.

For example, Fig. 4 represents the information connectivity of over 800 million web documents (S. Lawrence, 1999) collected by a net-

crawling software robot in 1999. Notice the naturally occurring hubs in the evolving global information web of 1999. Today the phenomena is even more dramatic and more complex. Researchers have concluded that the net-centric environment cannot be correctly understood from the traditional systems engineering worldview of information technology systems and system management.

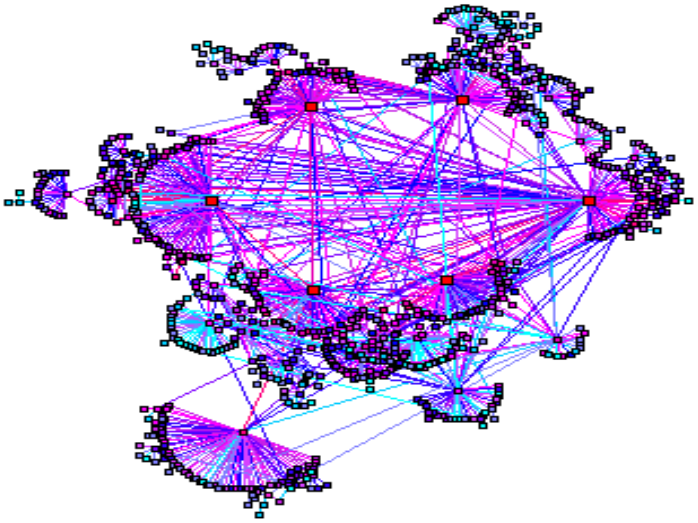

Fig. 4. Interconnections of 800 Million Web Pages, 1999

Furthermore, our information assets are too vast to be under the direct ownership or centralized administration of a handful of organizations. Information is produced and consumed "everywhere" just as cities fill our colorful air travel map. From the organizational relationships within the DoD information economy to the external information relationships between specialized DoD suppliers, the net-centric environment has already transformed the future of the military. To repeat an old cliché, *"The Future is Now."* A very basic question remains, *"what is actually going on and how will it effect military operations?"* The DoD and industry are rapidly turning to current topics in complex systems theory to serve as intellectual guideposts.

The influence and implications of global information networking is an astounding phenomena with vast social and organizational implications. In net-centric architectures, the performance of any single organization or autonomous maneuver unit may be influenced

by the characteristics and structure of the net-centric environment as a whole. These agile and virtual relationships influence the combined effectiveness of its many interdependent information components, including sensors, shooters, suppliers, intelligence analysts and other virtual team members. Therefore, the concepts of net-centric architecture and the power of cognitive networks have an enormous impact on all aspects of our military operations, from both a tactical and a strategic perspective.

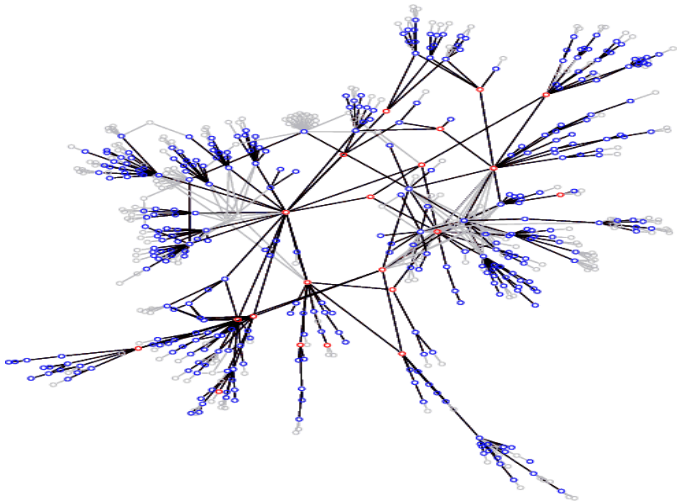

Fig 5. A Historical Depiction of Core Internet Service Providers

Complex systems theory guides us to understand that information capabilities tend to organize themselves around the notion of naturally occurring hubs. Fig. 5, a graphical representation of core Internet service providers over ten years ago, illustrates this phenomena. Like their biological counterparts, the new global information economy can be characterized as a large number of loosely interconnected participants who greatly depend on each other for their mutual effectiveness and survival. The effectiveness and robustness of participants in the information economy greatly depends on interactions with the other members of the economy.

Therefore, we offer that the notion of the "global information grid" is more accurately described as the "global information economy." In reality, there is no "grid"; there is an information economy facilitated by myriad underlying, and often overlapping, information

and social networks. It is important for net-centric architects to leverage the body-of-knowledge of complex systems theory so they may create innovative ways to characterize the collective health and effectiveness of this new global information economy.[5]

Complex systems theory has been used to help us understand the spread of forest fires, terrorism and disease. Complex system theory is used when researchers study the effects of crowd panic in a burning building. This body-of-knowledge is also used in the DoD as military researchers explore "swarms" of small, lightweight networked vehicles and munitions in combat. Terrorist activities and criminal behavior are also analyzed from the perspective of self-organization and complex systems theory.

To summarize, complex systems theory approaches to net-centric architecture helps us develop important practical knowledge and understanding of the "real world." Traditional systems and technology-centric approaches have failed to yield sustainable architectural results for a boundless sea of global information and information capabilities. The body-of-literature on complex systems theory suggests that both biological systems, and complex human-designed systems (like the Internet) tend to self-organize around naturally occurring hubs. Furthermore, it has been suggested that, just like our own human body, the overall capability of an emergent information economy is much greater than the sum of its many individual components and parts. New, unpredictable capabilities will emerge, most without design or forethought, based on the inherent properties of how complex systems self-organize and self-synchronize.

[5] Three cardinal measures of global economic health were developed by Iansiti and Levin from their work with biological ecosystems applied to business theory. They postulated that productivity, robustness, and niche creation were the leading indicators to measure business ecosystem health. Another observation from a review of the current literature on business ecosystems and complex systems theory is that emergent phenomena in both the natural and the human-designed world of cyberspace can be more accurately understood when viewed "as a whole" instead of "reduced" to overly simplified (and often fictional) architectural views and artifacts.

In many areas of science and technology, from national security policy to medicine, there are successful examples for turning to complex systems theory and biological metaphors for describing the characteristics of the new global information economy. Our journey along this path leads us to the "cities metaphor" used in this paper. The "cities metaphor" is a practical and easy to understand example of a "scale-free network," discussed in the next section.

4 Scale-Free Networks and Hubs

Further supporting our use of the "cities metaphor," and its relationship to service-oriented architectures in the global information economy, is the notion of *scale-free networks,* illustrated in Fig. 6. Using a Web crawler in 1998, physicist Albert-Laszlo Barabasi and his colleagues mapped the "connectedness" of the World Wide Web. They were surprised to discover that the structure of the World Wide Web did not conform to the then-accepted model of random connectivity. To the contrary, their experiment yielded a connectivity map that they called *scale-free*.[vii] [6]

Scale-free networks also support the infamous *small-world* concept.[7] In scale-free networks, like the various networks illustrated in Fig. 2 and Figs. 4-6, it only takes a few hops (or mouse clicks) for one network actor to be connected with another actor. Like the Web, many information services are accessible through one of the Web's well-connected hubs. Google's™ search portal is an example of an extremely well connected information search and discovery hub that services a vast information economy. Amazon™ and e-Bay™ are also examples of two well-connected electronic business hubs.

[6] Hubs tend to form naturally in all complex systems and networks. This net-centric characteristic is widely seen throughout natural and human-designed complex systems. For example, the Internet and the World Wide Web provide concrete examples of the importance of hubs and linkage patterns. The Internet, a complex system with a boundless number of diverse participants with no centralized control or authority, has rapidly evolved to enable the new global information economy.

[7] The reader may recall the popular *small-world* notion that there are only six degrees of separation between any two people in the world.

These information hubs provide stability and niche value creation in a critical segment of the emerging global electronic marketplace.

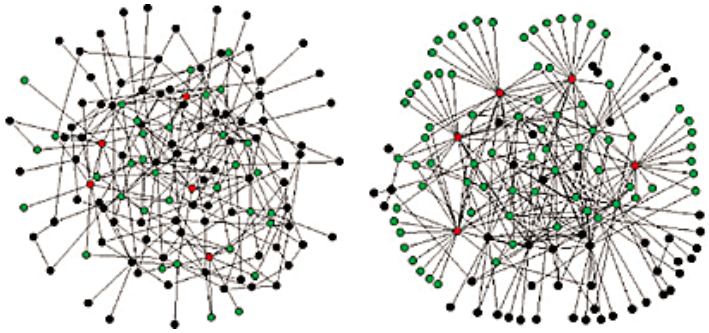

Fig. 6. Random (L.) and Scale-Free (R.) Networks

Scale-free network theory also helps us to better understand the abstract notion of component granularity in a service-oriented architecture; this is the basis for the "cities metaphor" used throughout this paper. Just like scale-free networks and biological systems, the notion of hubs are critical to understanding the new global information economy. Contrary to popular belief, *"Everything is not directly connected to everything,"* as some might inaccurately lead us to believe. However, in scale-free networks "everything" can be rapidly discovered by exploiting the notion of hubs and the linkages to and between these hubs of information capabilities.

Like their scale-free network counterparts, the new DoD global information economy is simultaneously influenced by internal capabilities and from interactions with the rest of the world. The boundaries of the information economy in the DoD need not, and typically does not, correspond to traditional military and organizational governance hierarchies. The DoD information economy is virtual, agile and adaptive, defined by the characteristics of our net-centric interactions and interconnected hubs of information.

Organizations in myriad diverse communities are largely influenced by the collective dynamics of many network participants. We

readily observe that the information economy greatly spans traditional organizational boundaries, just like our industrial economies expands beyond the boundaries of individual cities in our "cities metaphor." Furthermore, there is no centralized "command information economy." The cause-and-effect relationships within the new global information economy readily dwarf traditional organizational command and control hierarchies and boundaries.

Our readers are undoubtedly familiar with the current goals of the information sharing transformation in the DoD and the Department of Homeland Security (DHS). The DoD anticipates significant national security gains when "the cities" are sharing information, such as counter-terrorism intelligence. With these goals in mind, we turn our attention to a few of the architectural implications of service-oriented architectures in the DoD.

5 Implications & Recommendations

Scale-free networks are evident everywhere and at multiple levels of network abstraction. Our brains are scale-free networks of nerve cells connected by axons. Cells are scale-free networks of molecules connected by hubs of biochemical reactions. In fact, humanity consists of myriad interconnected scale-free networks of people linked in various types of formal and informal relationships. Food webs, materiel supply chains and the global economy are scale-free networks. The Internet, electric power grids and transportation systems are also scale-free networks.[8]

When scale-free nodes fail randomly, those networks typically perform better than random-connectivity networks because random failures are unlikely to harm a vital hub. On the other hand, if the failure of a node in a scale-free network is not random, for example a successful direct attack on a key hub, scale-free networks can fail catastrophically. Therefore, from an information systems

[8] Scale-free networks are clearly a key, frequently occurring pattern in nature; and its properties can be generalized from observing myriad instances.

perspective, the health and robustness of scale-free networks mimic the same characteristics found in their key hubs.

In the context of service-oriented architectures, the collective of DoD information resources resembles a new global economy that follows the principles of scale-free networks. This is the reason we have chosen the "cities metaphor" for this paper, and we continue to believe that the implications for service-oriented architectures arising in the Defense, or more precisely the National Security establishment, are greatly dependent on the underlying principles of scale-free network architectures. Ergo, we offer a few implications for the DoD's burgeoning SOA. These implications are not meant to be exhaustive and are offered as a basis for further discussion and elaboration.

The New Global Information Economy

Service-oriented architectures imply a boundless, powerful and adaptive global information economy that transcends established barriers to information sharing. Information systems and the organizations that support them are analogous to "cities" (or communities within cities). In order for "the city" to grow and prosper, the city must establish robust information commerce with other cities. This implies that a new global economic model for information sharing and information systems is on the rise. In this model, information entrepreneurs will compete for network user market share in a game that will require an appropriate level of government referees. While this activity rides the Department's massive, IP-based communication networks as a foundation, just as oxygen sustains animals and vegetation, the focus should be on the "payoff," players and processes.

Therefore, we recommend the DoD, at the appropriate time, revisit the term "Global Information Grid (GIG)" in the context of recent advances in scale-free network theory. We further recommend consideration of the term "Global Information Economy" as a potential replacement, or further elaboration, for "GIG." This is a natural and timely evolution of the original concept, just as the

horizontal integration idea of the 1990s has evolved into the ecosystem model.

To be clear, we are recommending much more than a *"name change."* We are recommending that the process of advocating and allocating resources and the government acquisition process be appropriately altered to foster the fielding of capabilities that fit this global information economic model. We affirm the importance of moving from a requirements-based approach to a capabilities-based approach. We urge establishing processes that incubate net-centric capabilities and we advocate moving from *"purpose built systems"* to fielding capabilities that encourage users to discover and use existing and future capabilities to meet their mission and business needs.[9]

Scale-Free Networks, "Cities" and Hubs

The "cities metaphor" is an easy-to-visualize picture for the new global information economy and service-oriented architectures that are growing on DoD intranets and globally through the World Wide Web. Hubs of information capabilities are both naturally occurring and self-organizing, as are almost all world cities. As net-centric architects and planners, our objectives should not be to integrate or to decompose "the cities." Instead, our goal should be to develop viable economic models and net-centric architectures for sharing information between "the cities" and, occasionally, to start a city by design (i.e. Reston, VA or Columbia, MD). Like urban planning or agriculture, certain features of city growth can be influenced to the good, but overall, the forces of nature are in charge.

[9] The reader only needs to examine the powerful impact Google™, e-Bay™, PayPal™ and Amazon™ have had on our economy, on our work and our daily lives to gauge the possible outcomes we can and will achieve. Initially, few in government or industry envisioned the impact these capabilities would have on the lives of hundreds of millions of people across the globe. We must enable the full power of net-centric thinking and the model of the new global information economy to spawn the next generation of genuine transformational thinking and systems. Only then will we achieve the military and national security outcomes our citizens dream of achieving.

The "cities metaphor" implies that there will be a powerful natural selection process for future service-oriented architectures, far more powerful and influential than top down control. This worldview implies that "cities" must develop the equivalent of the traditional "chamber of commerce" that publishes their information capabilities and actively promotes these capabilities to other "cities."

In addition, the DoD should resist the temptation to decompose "cities" into many smaller "communities" that are not naturally occurring or, conversely, to resist such decomposition where a natural tendency in that direction is recognized. Service definitions should be kept at the highest layer of abstraction economically feasible to allow for change. For example, if the Global Command and Control System (GCCS) can be defined as a "city," then GCCS should promote their aggregate capabilities just as a metropolitan chamber of commerce would promote the capabilities of their city.[10] We advise DoD to work aggressively to avoid spending resources on the technical decomposition of "cities" and hubs where not necessary. In a complex adaptive environment, vigorous control measures can have unintended consequences, and history says these are generally negative.[11]

Instrument, Monitor and Protect "the Cities"

From the global information security perspective, it is not economically feasible to protect and defend every information resource within a "city" dispersed as they are in a many-to-many architectural design. Likewise, it is not economically feasible to monitor the health and productivity of every individual information

[10] On the other hand, GCCS, as an aggregate information capability, may be too coarse of a service-level abstraction. This may be an excellent topic for a follow-on paper.

[11] The current governance processes, while helping ensure appropriate stewardship of our nations tax dollars, may well be unintended "governors"(like governors on carburetors) that dampen or restrict achievement of full potential. While we have made progress, the current DoD architecture reference models and the Federal Enterprise Architecture framework are merely modifications of the old "A," "B" and "C" specifications of the systems development era. These frameworks are good for decomposing work in purpose built systems, but they are not likely to enable us to achieve the full promise of net-centric thinking in a global information economy.

service-provider. The boundaries of "cities" are the optimal places, from an economic perspective, to instrument, monitor and defend the global information economy. This, in effect, defines the "cities" as enclaves and the appropriate defense-in-depth and "defense-in-breadth" security strategies should be employed based on the city-enclave model.

Emergence in the Global Information Economy

Future DoD programs will, by the very nature of (or in some instances in spite of) federal acquisition rules, work to design and acquire net-centric capabilities. The DoD should resist the notion that a global information economy can be adequately decomposed into components, directly purchased or "acquired," and sufficiently integrated to achieve the possible maximum benefit. The new global information economy for the DoD eschews monopoly; a healthy economy arises out of loosely controlled competition and cannot be directly purchased nor designed.[12] In fact, we believe the greatest power of net-centric architectures will be found in future capabilities that are neither predictable nor obtainable by direct engineering analysis and systems design. For this reason, it is important to enable a DoD global information economy that evolves along the same lines of how national and world "cities" have evolved, from a global economic perspective. The new global information economy is inherently unpredictable but largely self-synchronizing. Its natural evolution will largely take healthy directions, but serious dysfunction can arise. The best we can do is to facilitate what appears to be healthy growth and find innovative ways to avoid the spread of "urban blight." As we have learned from urban planning, a great deal of the blight results from old, uninformed, top down regulatory schemes that tried to impose rigid adherence to a logical model. We should lay the net-centric foundation for future military personnel to innovate and improvise based on unpredictable future threats, potential chaos, and evolving national security requirements.

[12] This is a key point. There is no overall top-down 'enterprise design' for the industrial economy. The same holds true for the information economy.

6 Concluding Comments

Our implications and recommendations for service-oriented architectures are based on the application of complex systems theory and, in particular, scale-free networks, to the information sharing goals of the DoD. Our research and analysis along this path has moved us toward the "cities metaphor" to suggest a way forward for advocating, resourcing and implementing net-centric and service-oriented architectures. From this advanced school-of-thought, we have formed a basis for the implications of SOA in the DoD and have offered a minimal set of recommendations. These implications and recommendations are not exhaustive; and are designed to serve as guideposts for further elaboration and development. We hope that the implications and recommendations offered in this paper will help evolve the DoD toward cost-effective and robust information sharing in the new global information economy.

We suggest that the evolution to a global information economy is the quintessential transformation required for our national security. This critical area requires creative and innovative research. Areas for future research include the application of game theory, social dilemmas, and various economic models[13] to SOAs, information technology portfolio management, information sharing behavioral models and enterprise architecture.

[13] For example, see Axelrod, Kollock, and Poundstone in the Additional Reading section of this paper.

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Public Release Approval

Review and approval of this paper by the Department of Defense for public release does not imply Department of Defense endorsement of factual accuracy or opinion.

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