13th ICCRTS

C2 For Complex Endeavors

Information Content For Adaptive Network Performance For C4ISR Systems-of-systems: Queuing Theory And Axiomatic Design Approach

K. Nyamekye, Integrated Activity-Based Simulation Research, Incorporated, Rolla MO 65401

POC: Dr. Kofi Nyamekye, President & CEO
Integrated Activity-Based Simulation Research, Incorporated
Rolla, MO

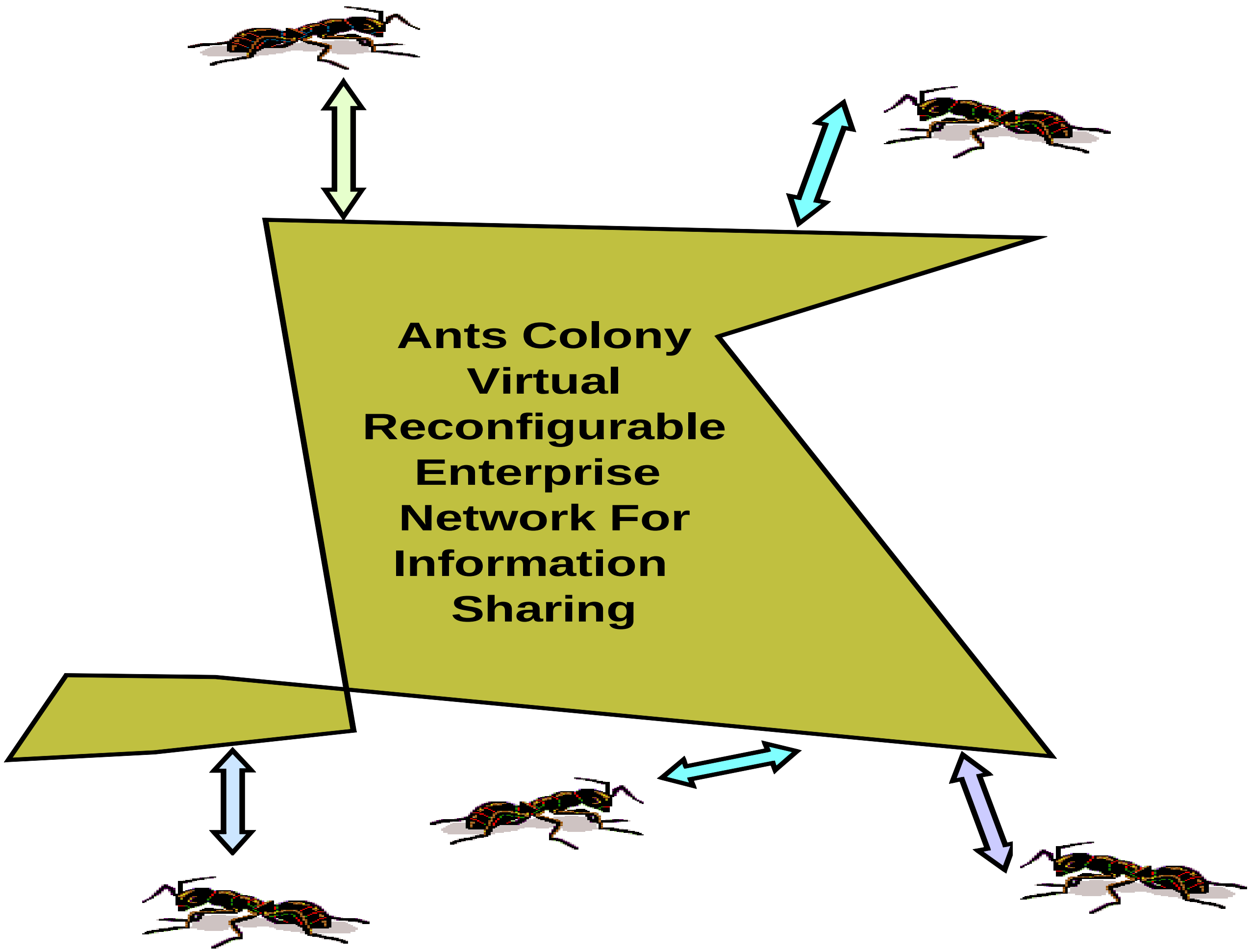
Tel: 573-341-2141; Mobile Tel: 573-647-1702

Email: kofinsoyameye@earthlink.net

Topics: Networks And Networking; Modeling And Simulation; C2 Assessment Tools And Metrics

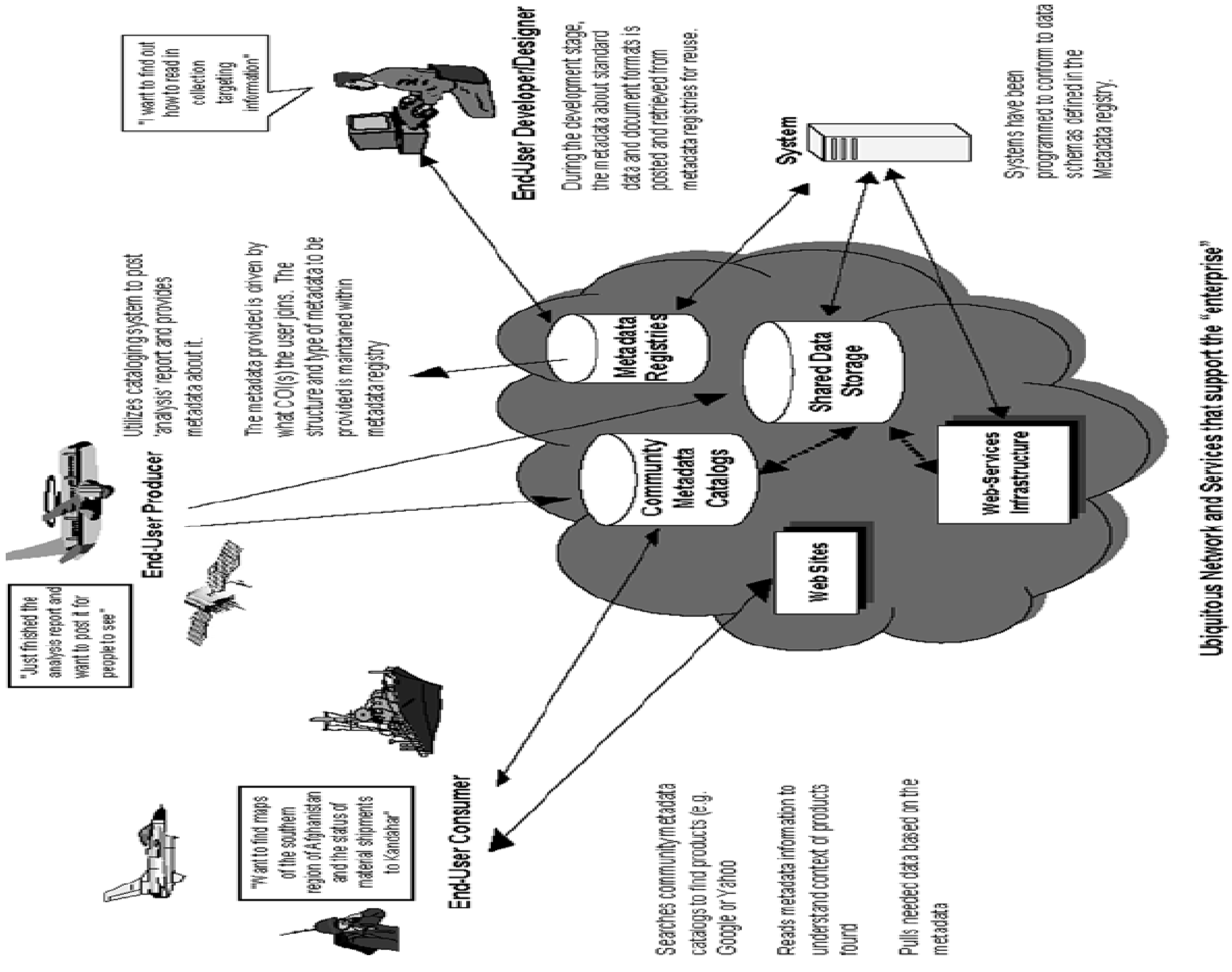
OVERVIEW

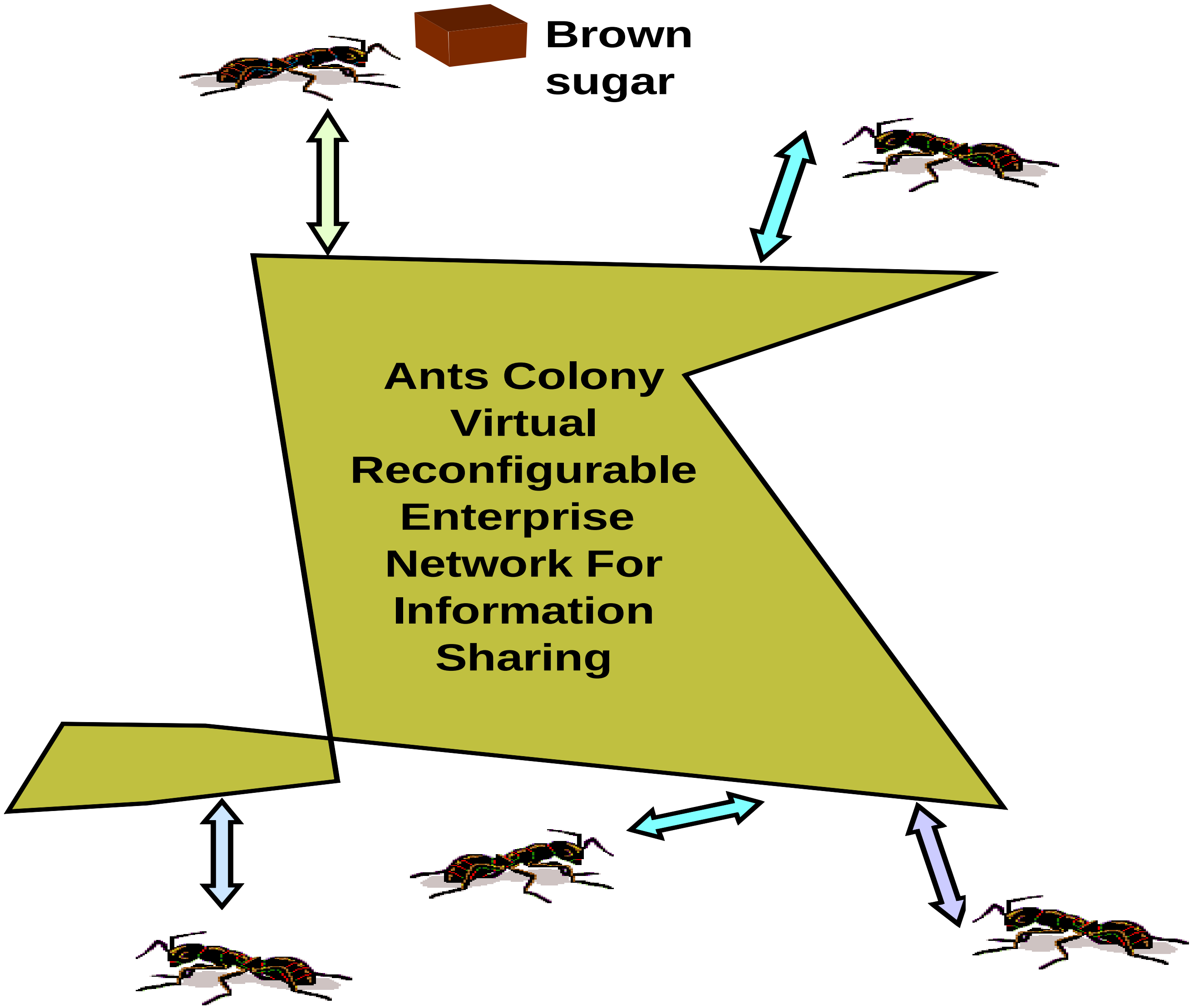
- DISCUSS ANTS COLONY AS AN EXAMPLE OF AN IDEAL NET-CENTRIC VALUE SYSTEM
- MAKE AN ANALOGY BETWEEN ANTS ADAPTIVE NETWORK AND DOD NETWORK FOR NET-CENTRIC SYSTEM
- DISCUSS THAT NETWORK SCIENCE IS AN EMERGING SCIENTIFIC DISCIPLINE AND THUS THE SCIENTIFIC CONCEPTS ARE NOT MATURED TO PREDICT THE NETWORK PERFORMANCE FOR NET-CENTRIC SYSTEMS
- DISCUSS TYPES OF NETWORK, PROPERTIES OF NETWORK, NETWORK CLASSIFICATION, AXIOMATIC DESIGN FOR NETWORK PERFORMANCE MODEL
- DISCUSS QUEUING MODELS AND C4ISR SoS DESIGN AS A PREREQUISITE FOR NETWORK PERFORMANCE MODEL
- DISCUSS INFORMATION CONTENT FOR NETWORK PERFORMANCE
- DISCUSS SERVICE-BASED SIMULATION MODELS AND EXPERIMENTAL TESTS
- CONCLUSIONS
- QUESTIONS

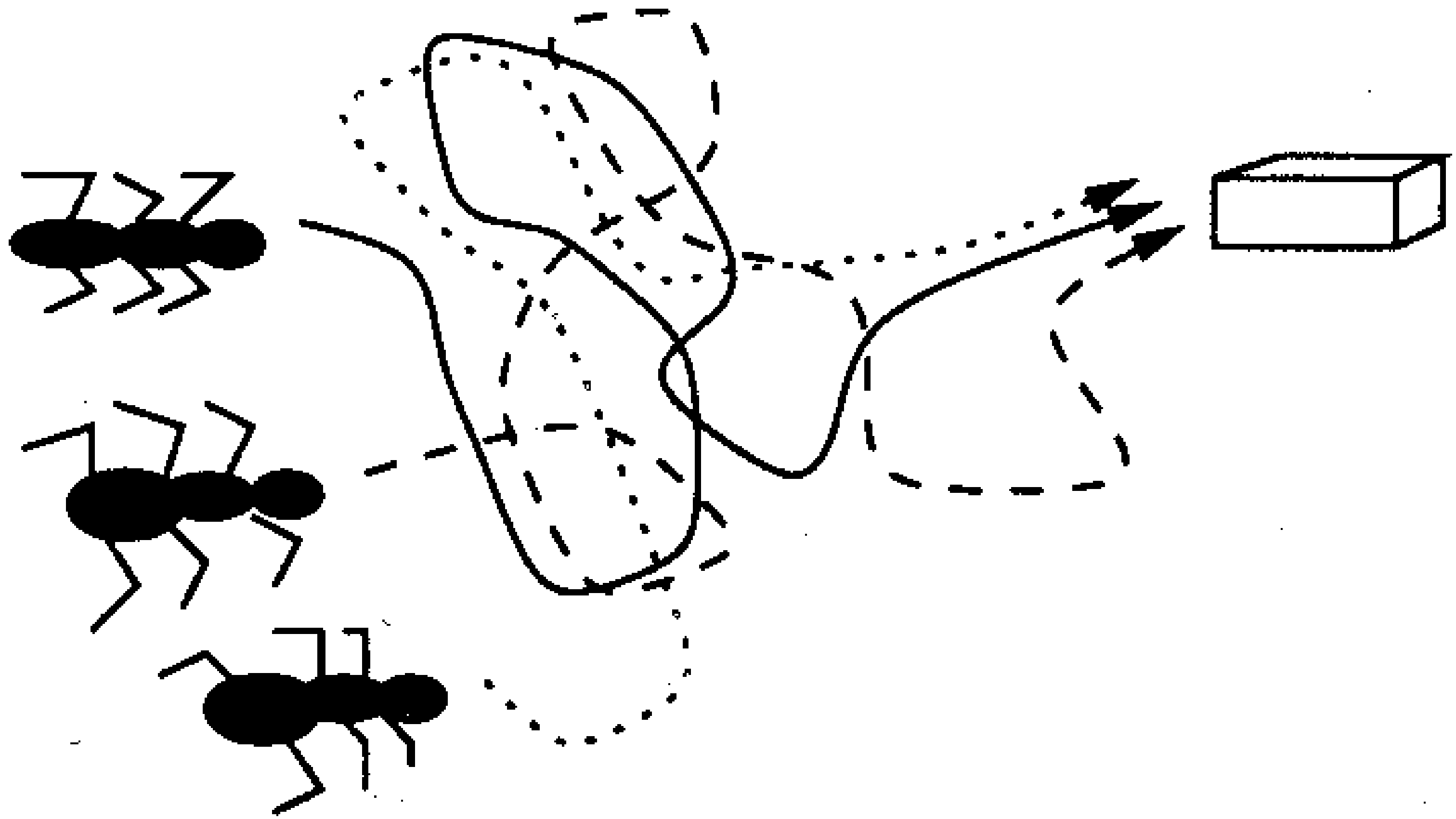


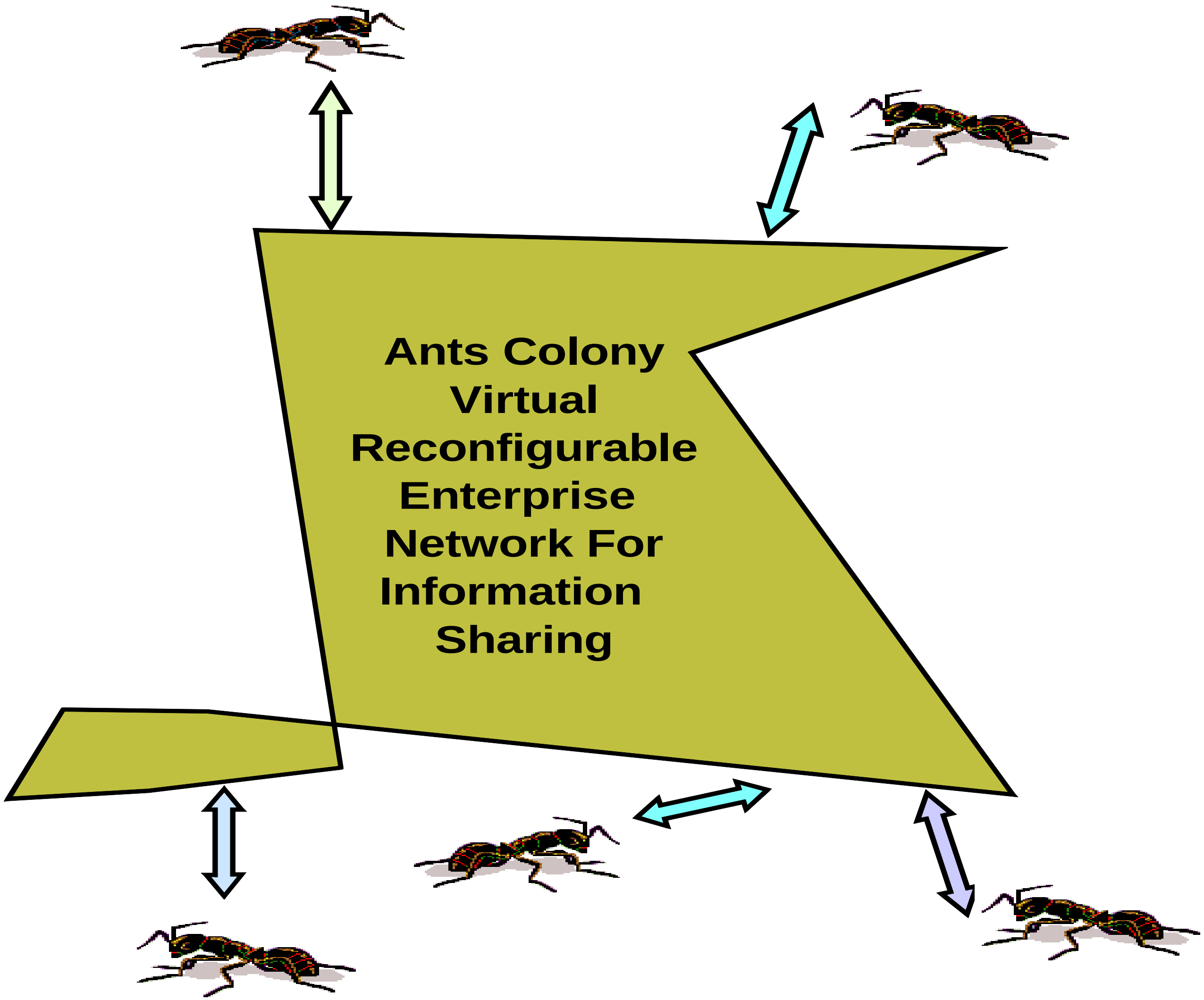
COMMAND (BUSINESS GOAL OR MISSION) and CONTROL (GAME PLAN) FOR ANTS COLONY

ANTS ADAPTIVE NETWORK <u>VERSUS</u> NETWORK FOR NET-CENTRIC SYSTEM [ALBERTS ET AL. 2003.]




Brown
sugar
Ants Colony
Virtual
Reconfigurable
Enterprise
Network For
Information
Sharing





EXTREMELY CHALLENGING TO PREDICT THE PERFORMANCE OF SUCH AN ADAPTIVE NETWORK; SCIENTIFIC CONCEPTS ARE NOT MATURED FOR MODELING THE PERFORMANCE OF SUCH NETWORKS

NETWORK TYPES

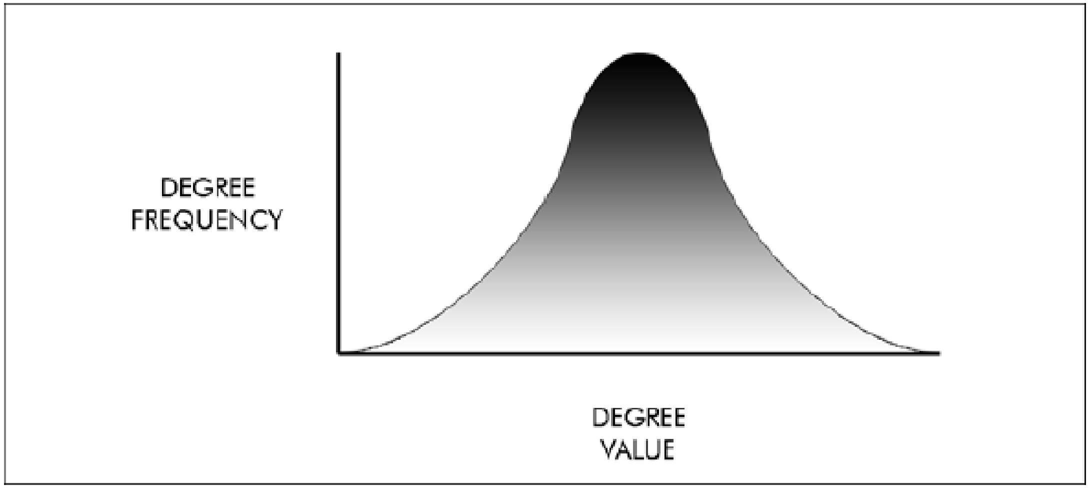
- Physical network
- Communications network, e.g., Internet
- Information network, e.g.,Web portal, Joint Battlespace Infosphere (JBI)
- Cognitive network
- Social network

PROPERTIES OF NETWORK

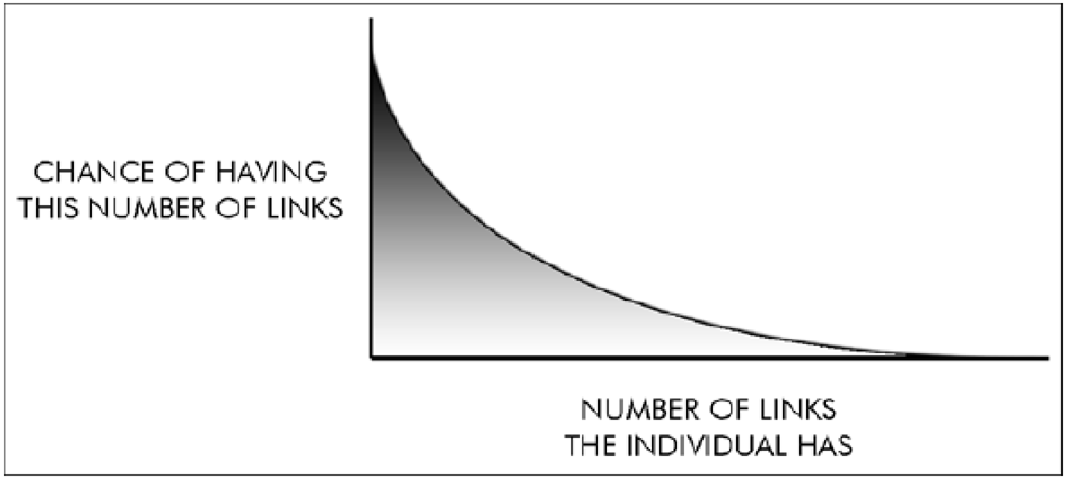
- ***Average degree -- measures the average number of links connected to a node in the network***
- ***Clustering coefficient -- measures how well the neighbors of a given node are linked in the network***
- ***Average path length -- measures the average distance between two nodes of the network chosen at random***
- ***A network with high average degree, high clustering coefficient, and a low average path length, will achieve overall best performance.***

NETWORK CLASSIFICATION

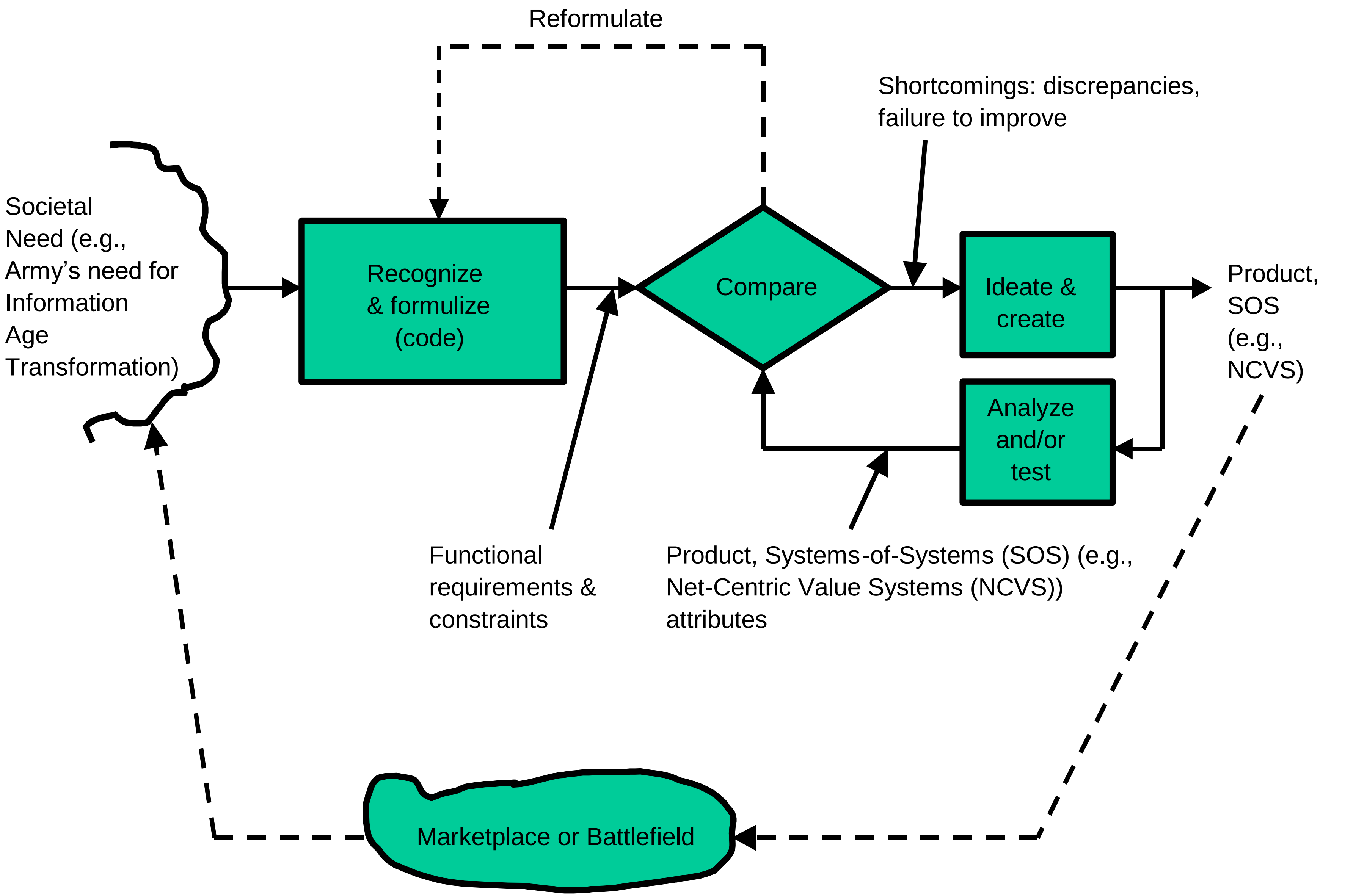
- Regular Networks, e.g., the retina of the eye and the roads of some large cities; average degree of all nodes assumes the same value
- Random Networks -- have low average degree, low clustering coefficient, and low average path length
- Small World Networks -- have high clustering coefficient, and high average degree
- Scale Free Networks, e.g., Internet; have high cluster coefficient, low average path length, and a few nodes with a high average degree
- Question: Which combination of networks (hybrid network systems) would be ideal for adaptive C4ISR SoS?



The Frequency Distribution of The Degree of A Random Network [Atkinson et al. 2005]



The Frequency Distribution of The Degree of A Scale-Free Network [Atkinson et al. 2005.]



The Design Loop-As the Architecture for Systems-of-Systems (e.g., Net-Centric Value Systems, Future Combat Systems, etc.) Design [Modified Version of Nyamekye et al., June 2005 (CD Version); Wilson, D. R., Ph.D. Thesis, MIT, August, 1980.]

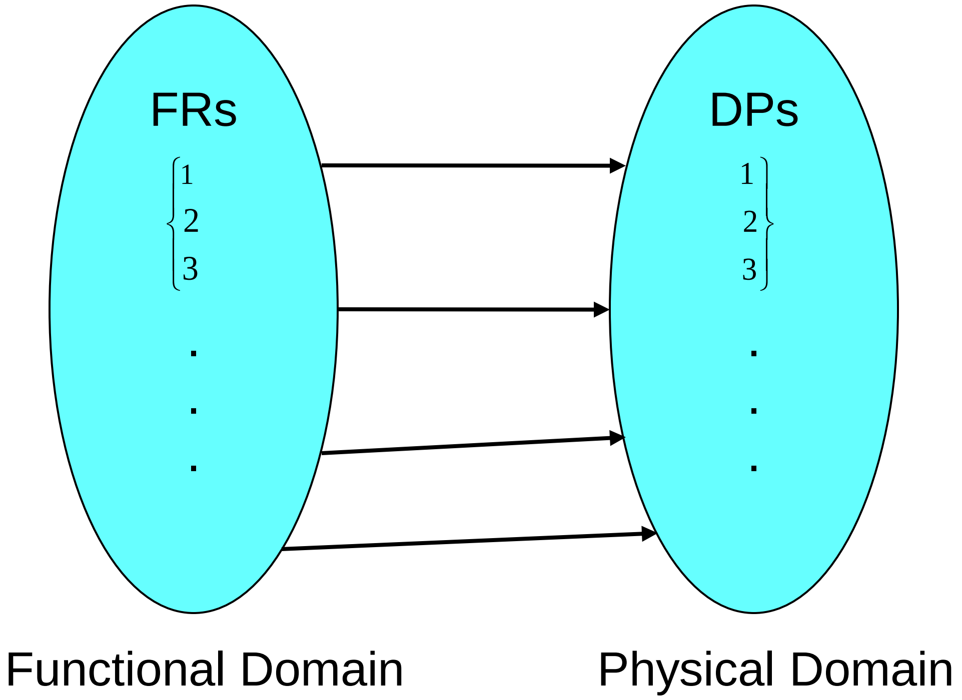
BRIEF OVERVIEW OF AXIOMATIC DESIGN– SUH FROM MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

TWO AXIOMS:

AXIOM 1: In a good design, the independence of functional requirements (FRs) is maintained.

AXIOM 2: The design that has the minimum information content is the optimal design.

In addition to the functional requirements, a set of constraints may also exist. Constraints are factors that establish the boundary on acceptable design solutions. For example, some designers treat cost as a constraint. On the battlefield, how much collateral damage, and how many casualties are "acceptable" in a theater operation, could represent the constraints [Alberts et al. 2003]. Constraints are very similar to functional requirements in character and attributes except that the independence of constraints is not required in a good design. Note: AXIOM 2 is analogous to Shannon Information Theory.



Mapping from the Functional Domain (or Space) to the Physical [Suh 1990]

$$\{FR_i\} = [DM]\{DP_i\}$$ .... **BASIC DESIGN EQUATION**

$\{FR_i\} =$ the vector that represents the functional requirements in the functional domain

$\{DP_i\} =$ the vector that represents the design parameters in the physical domain

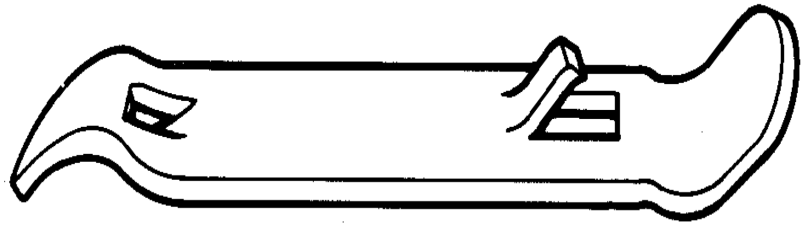
$[DM] =$ the design matrix that relates $\{FR_i\}$ to $\{DP_i\}$

The figure below shows can and bottle opener. This device satisfies two objectives or functional requirements (FRs). The FRs are fulfilled by the following physical solutions or design parameters (DPs):

Goal 1 (FR1): Open cans; DP1: Can Opener

Goal 2 (FR2): Opens bottles; DP2: Bottle Opener

If the requirements are not to perform these two functions simultaneously, then this physically integrated device satisfies two independent goals or functional requirements (FRs). Otherwise *coupling* occurs if both goals must be concurrently met with the same device. We can use Corollary 1 to redesign the device to eliminate coupling, while fulfilling both FRs simultaneously, with both DPs.



Another Example: Iraq Yusufiyah Case, June 21, 2006 – Major Caldwell CNN Transcript
http://transcripts.cnn.com/TRANSCRIPTS/0606/21/sitroom.03.html

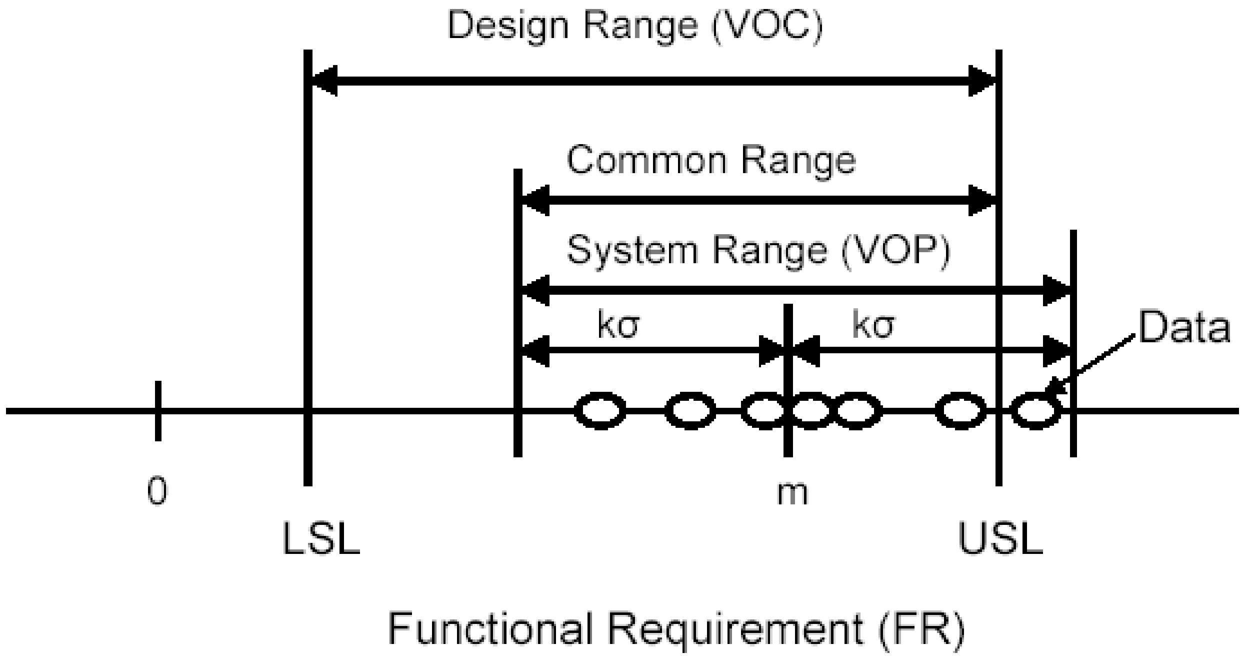
Goal 1 (FR1): Engage and defeat the enemy; DP1: 1 vehicle convoy of 3 soldiers
Goal 2 (FR2): Call the support group; DP2: 1 vehicle convoy of 3 soldiers

Equation 1

$$I = \log\left(\frac{system\ range}{common\ range}\right)$$

Equation 2

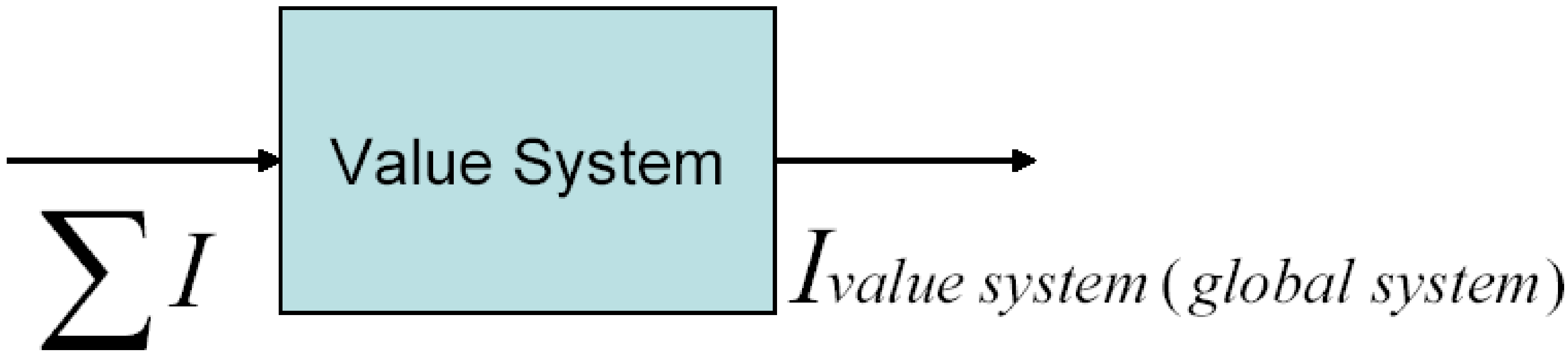
$$I_{value\ system\ or\ global\ system} = \sum I$$



Experimental values for Functional Requirement [Nakazawa 2001]

LSL = Lower specification limit
USL = Upper specification limit
k = a safety factor
m = mean value of process performance
σ = unbiased standard deviation of process performance

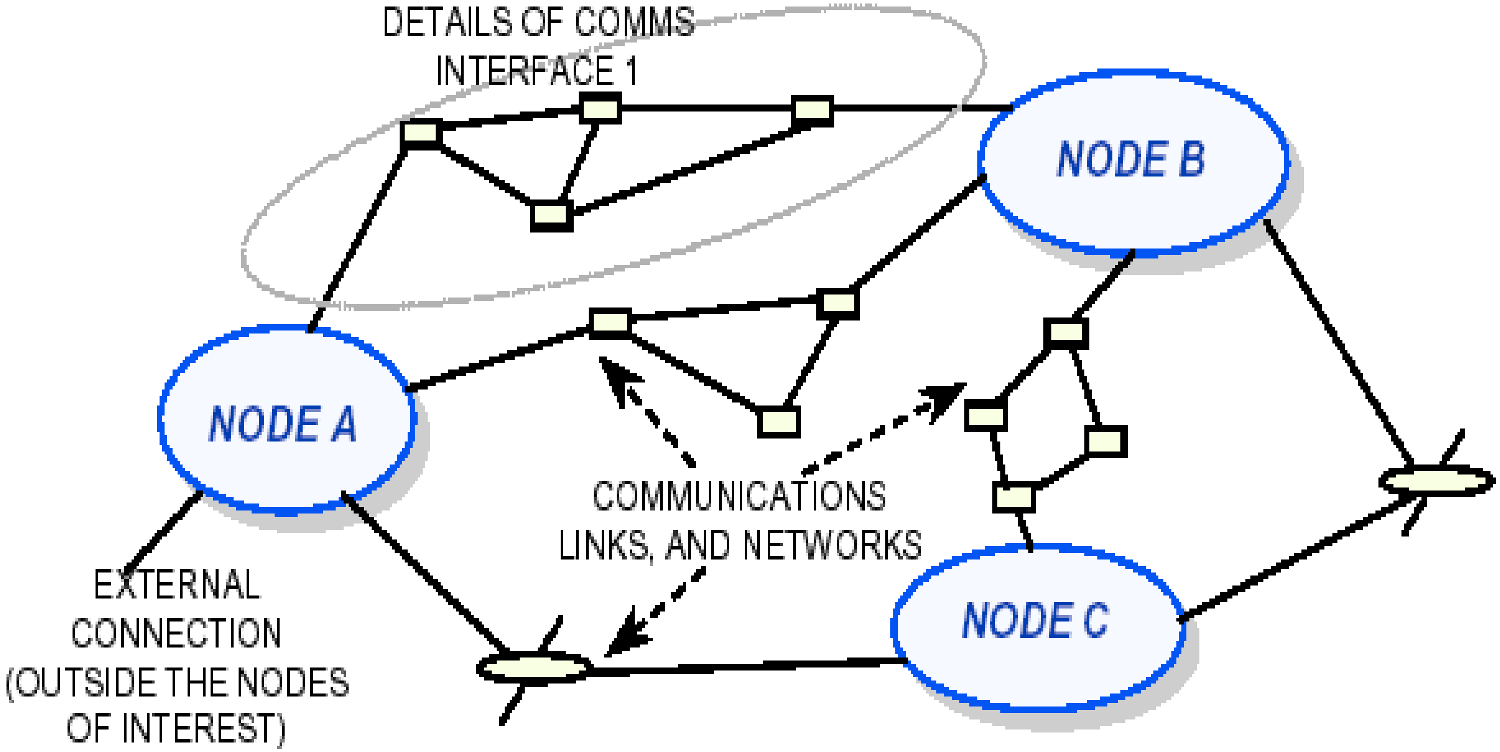
Illustration of Design Range and Common Range [Nakazawa 2001.]



I = Information Content (From AXIOM 2)
System Range = Voice of the Process (VOP)
Design Range = Voice of Customer (VOC)
Common Range = Amount of Overlap between VOC and VOP

Total Information Content, Equation 2.

COMMUNICATIONS NETWORK FOR QUEUING MODELS



Systems Communications Description, Inter-nodal Version (SV-2) [DODAF Version 1.5, Volume II April 2007.]; Small boxes represent routers, and the oval shapes represent satellites.

Equation 18

$$T = \frac{1}{\sigma_z}\left\{\prod_{r=1}^{\deg_z}(1-K_r))^{\omega}r\right\} + \sum_{i=1}^{O}\frac{\lambda_i}{\gamma}\left[\frac{\frac{\lambda_i}{\mu' F_i}}{\mu' F_i - \lambda_i} + \frac{1}{\mu F_i} + \frac{L_i}{SP} + \frac{1}{\sigma_z}\left\{\prod_{r=1}^{\deg_z}(1-K_r))^{\omega}r\right\}\right]$$

$$g(C) = \frac{e^{a+bC}}{1+e^{a+bC}}$$ Equation 19

$$T_C = \frac{T}{1-g(C)}$$ Equation 20

DESIGN OF C4ISR SYSTEMS-OF-SYSTEMS

- Power To The Edge can be applied in two ways for Integrated C4ISR SoS:
  - Design and architecture of C4ISR systems-of-systems (Infostructure)
    - COROLLARIES (DESIGN SCIENCE RULES) FROM AXIOMATIC DESIGN FOR C4ISR SoS
    - THEOREM M2 FROM AXIOMATIC DESIGN FOR C4ISR SoS
  - Organization and management of work (C2)

Among the corollaries and theorems derived from AXIOM 1 and AXIOM 2, the following four corollaries and a theorem, are essential for designing C4ISR SoS, namely [Suh 1990; Suh 2001]:

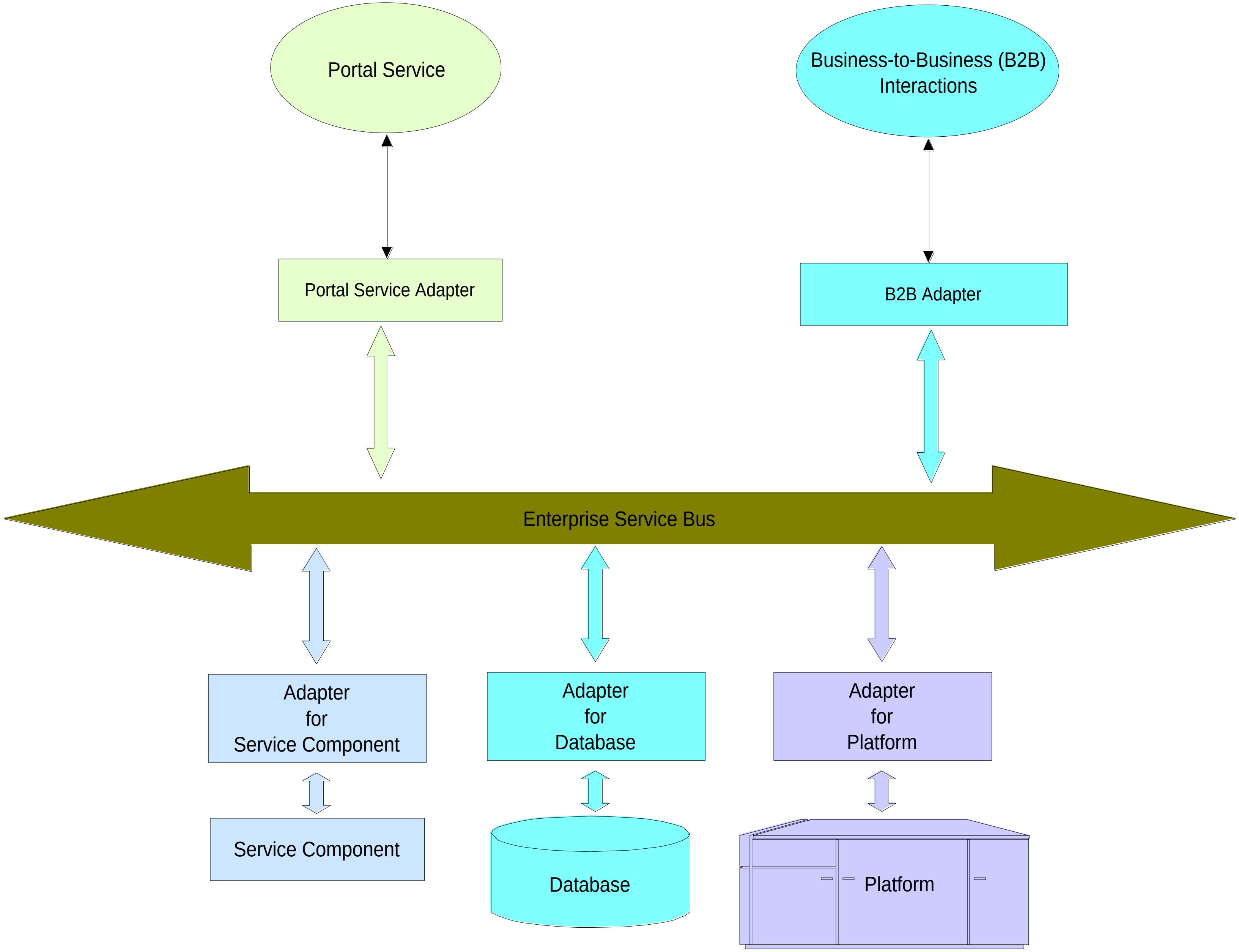
Corollary 1: Decoupling of Coupled Design: Decouple or separate parts or aspects of a solution if FRs are coupled or become interdependent in the proposed designs.

Corollary 2: Minimization of FRs: Minimize the number of functional requirements and constraints. Strive for maximum simplicity in overall design or the utmost simplicity in physical and functional characteristics.

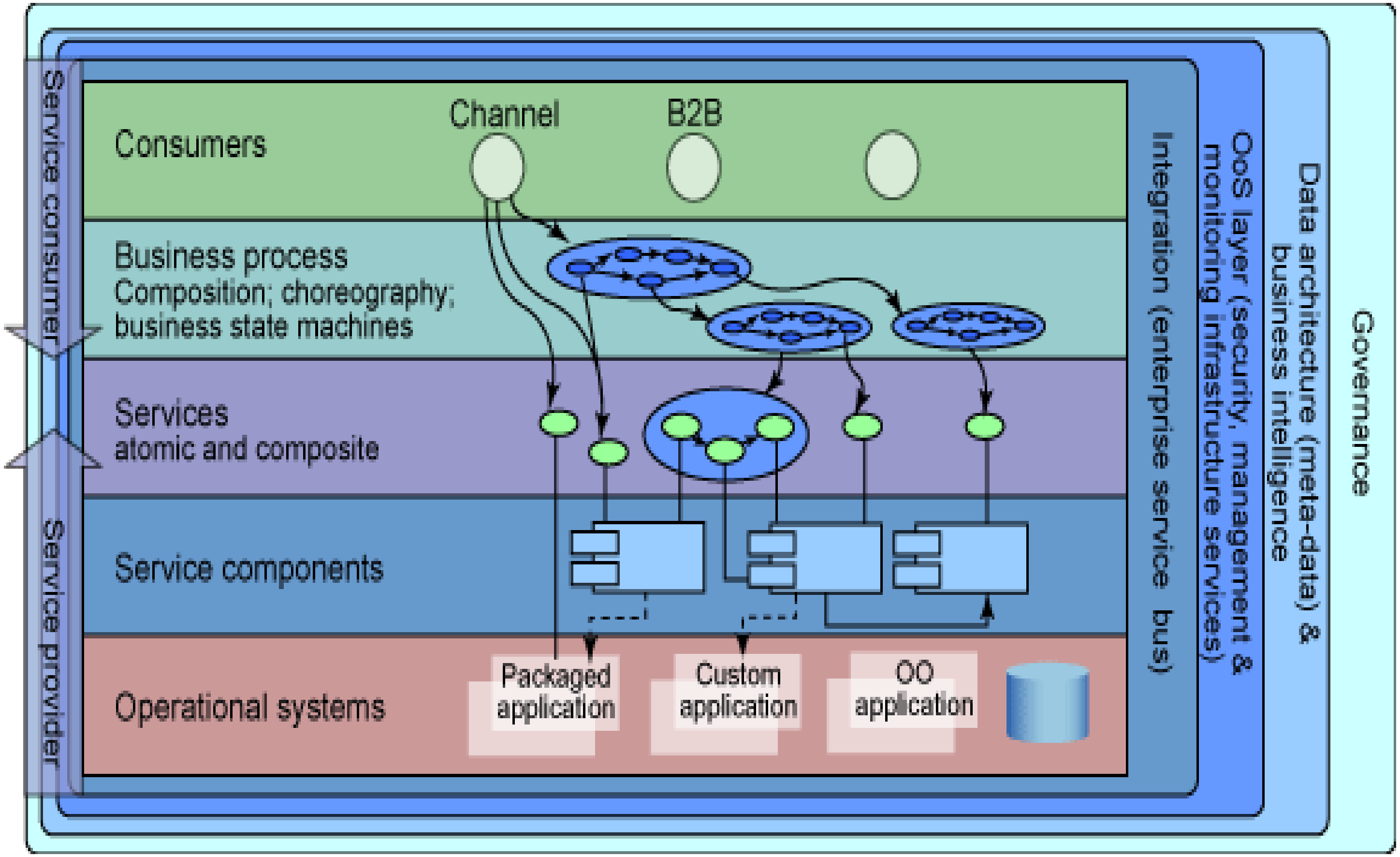
***Corollary 3: Integration of Physical Parts: Integrate design features into a single physical process, device, scientific concept, or system when FRs can be independently satisfied in the proposed solution*.**

Corollary 4: Use of Standardization: Use standardized or interchangeable parts, architecture, process, device, or system if the use of these parts, architecture, process, device, or system is consistent with the FRs and constraints. This corollary establishes the governance model for designing any large-scale system.

THEOREM M2 (Large System with Several Subunits) When a large (e.g., organization) consists of several subunits, each unit must satisfy independent subsets of FRs so as to eliminate the possibility of creating a resource-intensive system or a coupled design for the entire system.

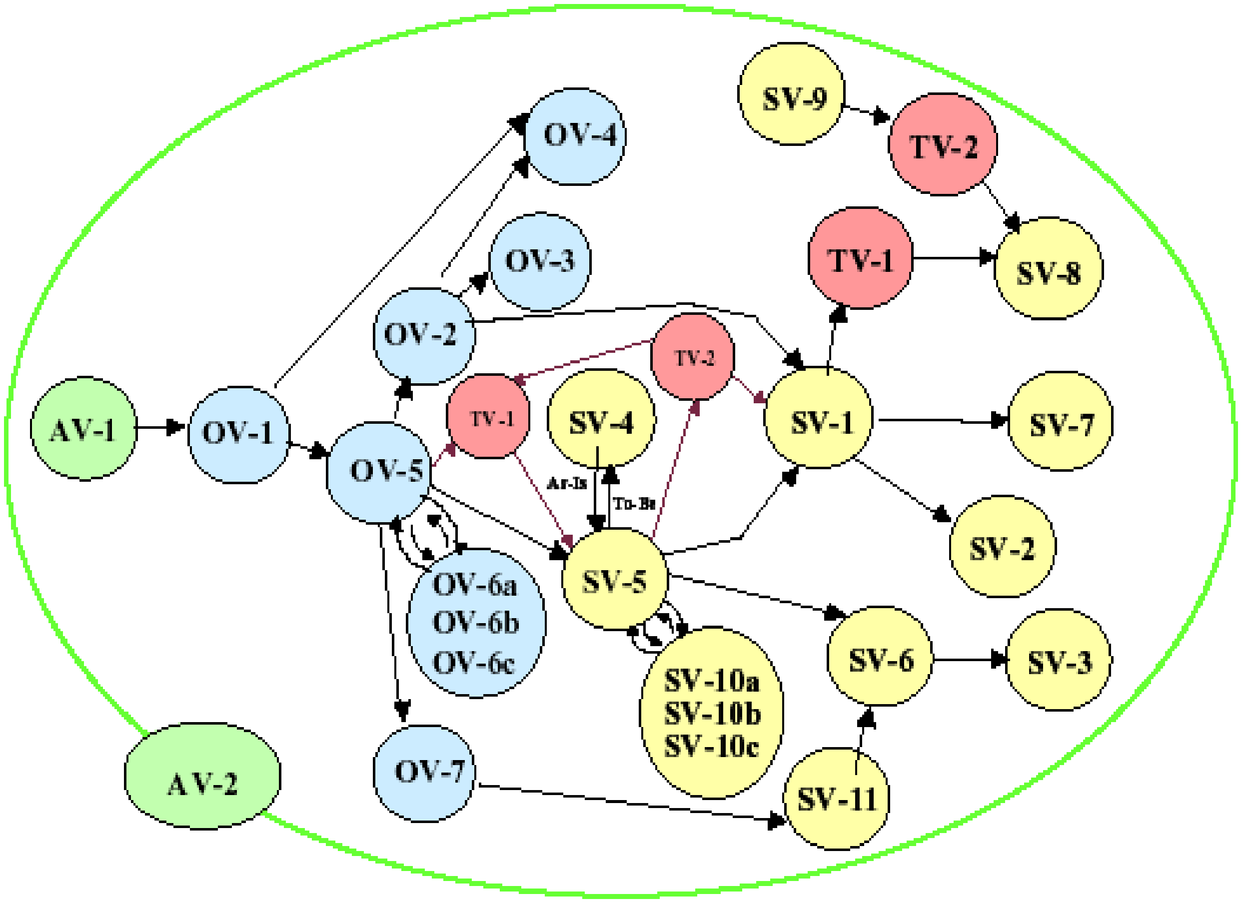


Enterprise Service Bus [Nyamekye June 2007.]



SOA = INTEROPERABILITY + AGILITY (FOR DESIGN OF ANY INTEGRATED VALUE SYSTEMS) WITH <u>GOVERNANCE MODEL</u> TO ELIMINATE STOVE-PIPED SYSTEMS-OF-SYSTEMS (SOS)

The Different Layers of Service-Oriented Architecture (SOA) [Arsanjani November 9 2004.]



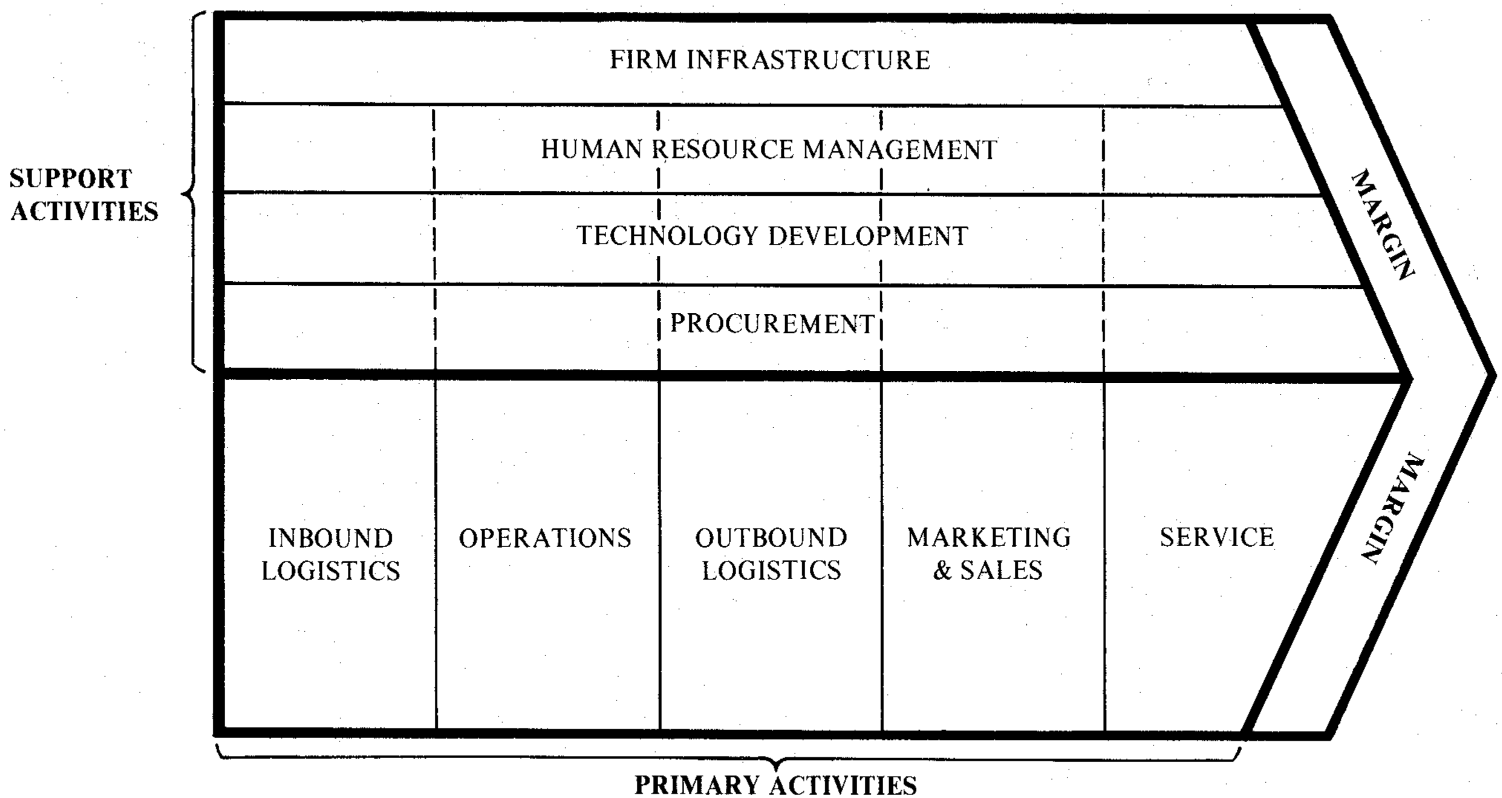
Relationships Among the Data Elements of DODAF
[DODAF Version 1, Volume II February 2004.]

Applicable View	Framework Product	Framework Product Name	Net-Centric Extension	General Description
All View	AV-1	Overview and Summary Information	✓	Scope, purpose, intended users, environment depicted, analytical findings
All View	AV-2	Integrated Dictionary	✓	Architecture data repository with definitions of all terms used in all products
Operational	OV-1	High-Level Operational Concept Graphic	✓	High-level graphical/textual description of operational concept
Operational	OV-2	Operational Node Connectivity Description	✓	Operational nodes, connectivity, and information exchange need lines between nodes
Operational	OV-3	Operational Information Exchange Matrix	✓	Information exchanged between nodes and the relevant attributes of that exchange
Operational	OV-4	Organizational Relationships Chart	✓	Organizational, role, or other relationships among organizations
Operational	OV-5	Operational Activity Model	✓	Capabilities, operational activities, relationships among activities, inputs, and outputs; overlays can show cost, performing nodes, or other pertinent information
Operational	OV-6a	Operational Rules Model	✓	One of three products used to describe operational activity—identifies business rules that constrain operation
Operational	OV-6b	Operational State Transition Description	✓	One of three products used to describe operational activity—identifies business process responses to events
Operational	OV-6c	Operational Event-Trace Description	✓	One of three products used to describe operational activity—traces actions in a scenario or sequence of events
Operational	OV-7	Logical Data Model	✓	Documentation of the system data requirements and structural business process rules of the Operational View
Systems and Services	SV-1	Systems Interface Description Services Interface Description	✓	Identification of systems nodes, systems, system items, services, and service items and their interconnections, within and between nodes
Systems and Services	SV-2	Systems Communications Description Services Communications Description	✓	Systems nodes, systems, system items, services, and service items and their related communications lay-downs
Systems and Services	SV-3	Systems-Systems Matrix Services-Systems Matrix Services-Services Matrix	✓	Relationships among systems and services in a given architecture; can be designed to show relationships of interest, e.g., system-type interfaces, planned vs. existing interfaces, etc.
Systems and Services	SV-4a	Systems Functionality Description		Functions performed by systems and the system data flows among system functions
Systems and Services	SV-4b	Services Functionality Description	✓	Functions performed by services and the service data flow among service functions
Systems and Services	SV-5a	Operational Activity to Systems Function Traceability Matrix		Mapping of system functions back to operational activities
Systems and Services	SV-5b	Operational Activity to Systems Traceability Matrix		Mapping of systems back to capabilities or operational activities
Systems and Services	SV-5c	Operational Activity to Services Traceability Matrix	✓	Mapping of services back to operational activities
Systems and Services	SV-6	Systems Data Exchange Matrix Services Data Exchange Matrix	✓	Provides details of system or service data elements being exchanged between systems or services and the attributes of that exchange

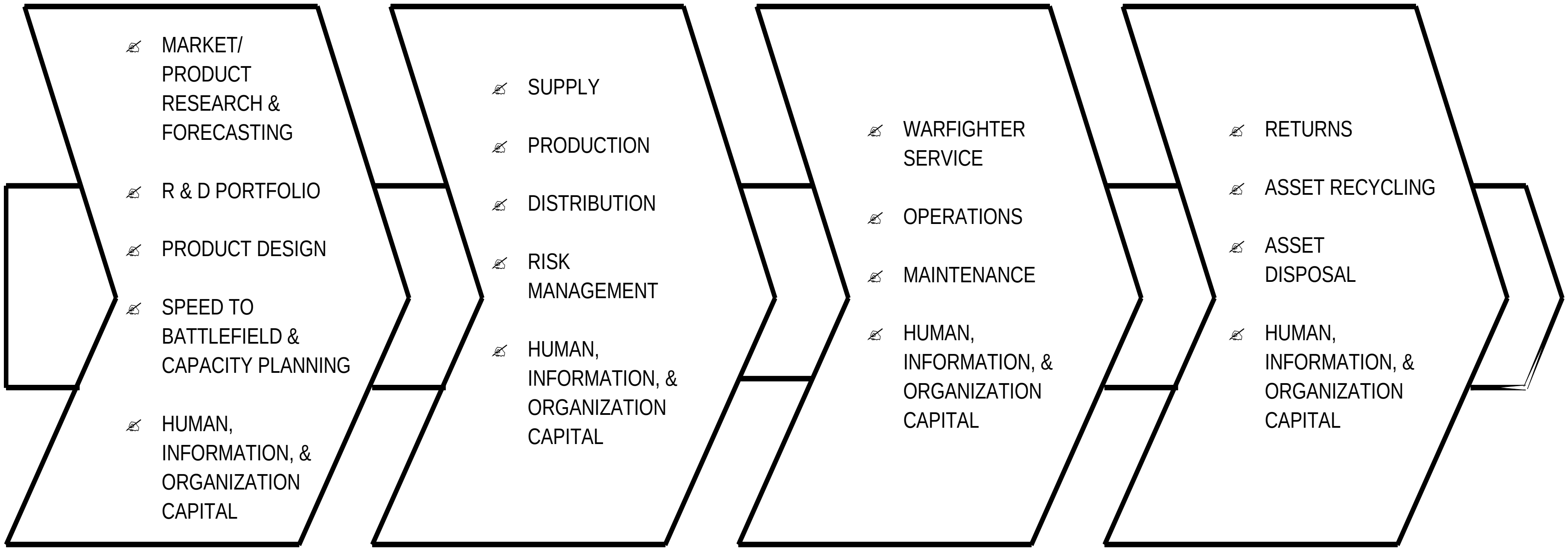
The 36 Products of (SOA)-Based DODAF [DODAF Version 1.5, Volume II April 2007.]

Applicable View	Framework Product	Framework Product Name	Net-Centric Extension	General Description
Systems and Services	SV-7	Systems Performance Parameters Matrix Services Performance Parameters Matrix	✓	Performance characteristics of Systems and Services View elements for the appropriate time frame(s)
Systems and Services	SV-8	Systems Evolution Description Services Evolution Description	✓	Planned incremental steps toward migrating a suite of systems or services to a more efficient suite, or toward evolving a current system to a future implementation
Systems and Services	SV-9	Systems Technology Forecast Services Technology Forecast	✓	Emerging technologies and software/hardware products that are expected to be available in a given set of time frames and that will affect future development of the architecture
Systems and Services	SV-10a	Systems Rules Model Services Rules Model	✓	One of three products used to describe system and service functionality—identifies constraints that are imposed on systems/services functionality due to some aspect of systems design or implementation
Systems and Services	SV-10b	Systems State Transition Description Services State Transition Description	✓	One of three products used to describe system and service functionality—identifies responses of a system/service to events
Systems and Services	SV-10c	Systems Event-Trace Description Services Event-Trace Description	✓	One of three products used to describe system or service functionality—identifies system/service-specific refinements of critical sequences of events described in the Operational View
Systems and Services	SV-11	Physical Schema	✓	Physical implementation of the Logical Data Model entities, e.g., message formats, file structures, physical schema
Technical Standards	TV-1	Technical Standards Profile	✓	Listing of standards that apply to Systems and Services View elements in a given architecture
Technical Standards	TV-2	Technical Standards Forecast		Description of emerging standards and potential impact on current Systems and Services View elements, within a set of time frames

The 36 Products of (SOA)-Based DODAF [DODAF Version 1.5, Volume II April 2007 (Continued).]



Porter's Generic Value Chain [Porter 1985] – Not Suitable for Creating DoD Net-Centric Enterprise Value Systems



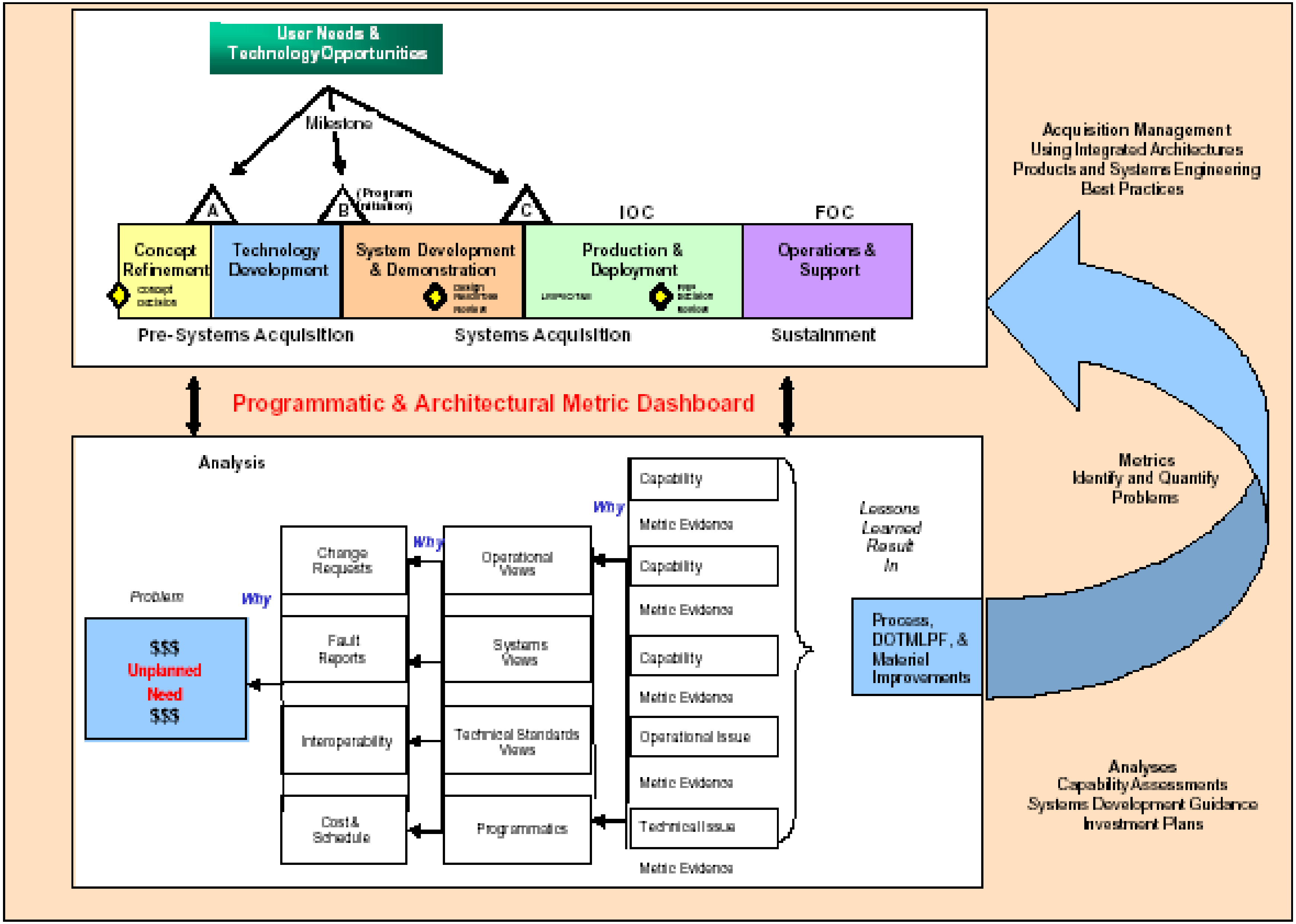
Create the Net-Centric enterprise.

Achieve operational excellence.

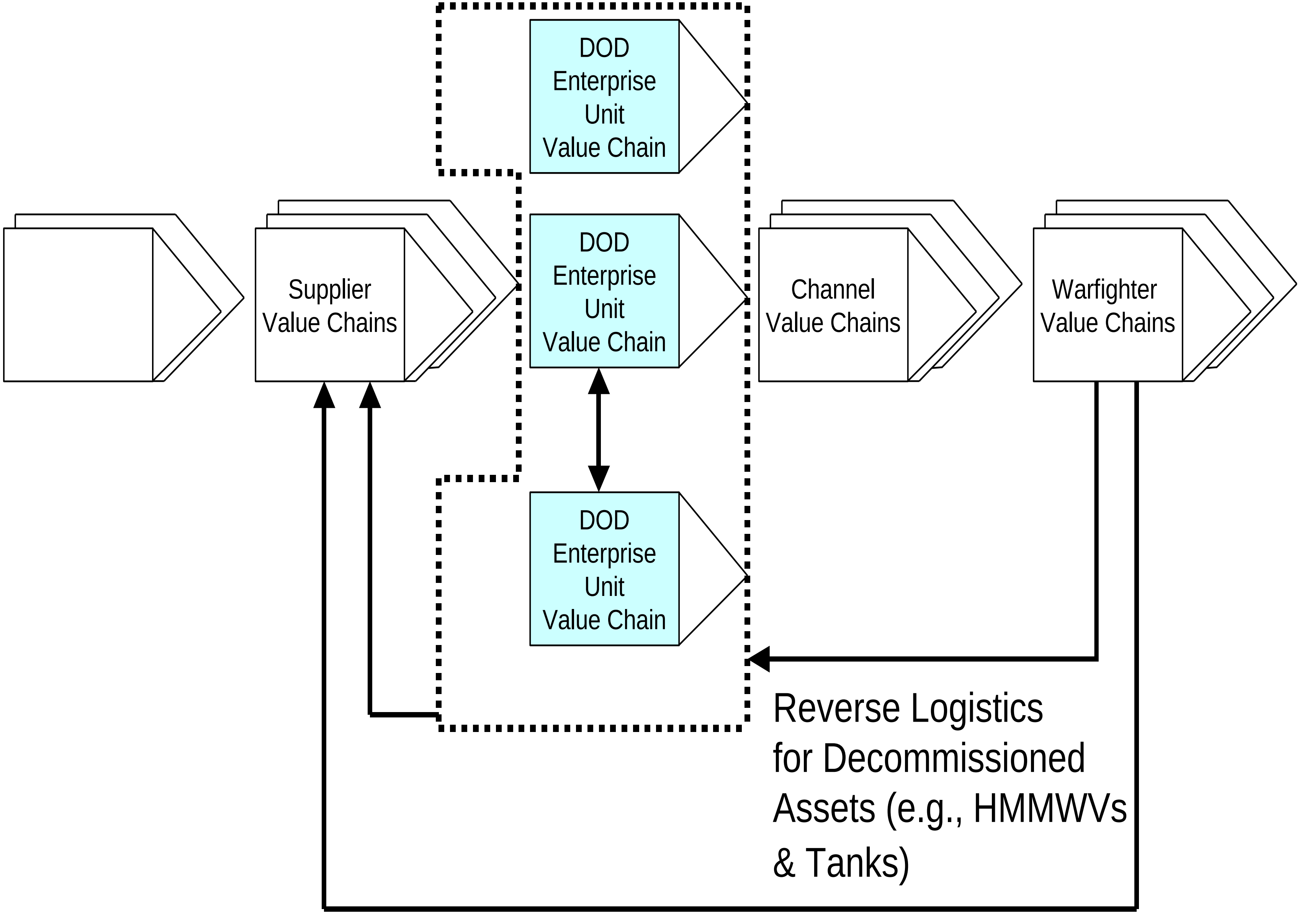
Provide superior warfighter service; achieve operational and maintenance excellence.

Design an innovative return channel to convert returned tangible and intangible assets into non-hazardous products to achieve a green ecosystem.

DOD Generic Net-Centric Enterprise Value Chain Model

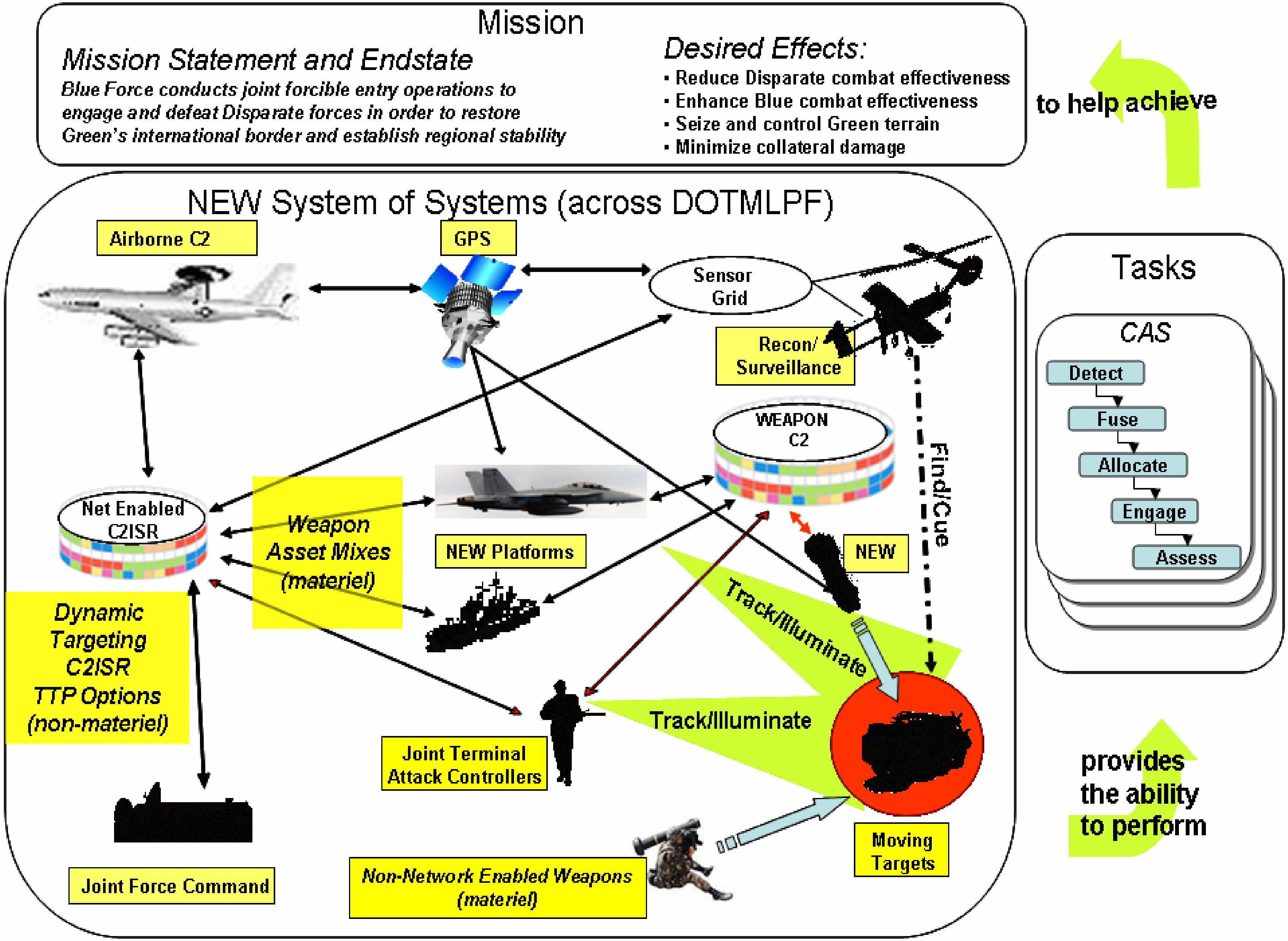


Acquisition Process and Architecture-Based Analysis [DODAF Version 1, Volume II February 2004.] – Similar in Concept To The DoD Generic Net-Centric Enterprise Value Chain Model



DOD Generic Net-Centric Enterprise Value System Model

The Concept Of Electronic Commerce In The DOD, Including The Relevant Business Areas And Support To The Warfighter Operations, [Defense Electronic Business 2000.]



Joint Network Enabled Weapon (NEW) Capability Operational Concept Graphic (OV-1), Depicting the ISR "Fuse" (Composite Task) [DODAF Version 1.5, Volume II April 2007.]

Using THEOREM 2 and Corollary 4 (the governance model), define the DOD Enterprise Level business processes and warfighter processes (see previous slide). The governance model is critical to eliminate departmentalized services (a critical ingredient for C4ISR SoS), such as below. Use Corollary 4 to achieve standardized processes throughout the C4ISR ecosystem. Use AXIOMS 1 & 2, Corollaries 1, 2, & 3, information content, to deign and evaluate the performance of the integrated C4ISR SoS.

SOA Services As Application Silos (Departmentalized Services) [Dejong April 15, 2007: "Used by permission from SD Times, BZ Media LLC. Copyright. All rights reserved."]

	SUBJECT DATABASES																							
PROCESSES	Customer	Budget	Financial	Vendor	Procurements	Materials inventory	Fin. goods inventory	Orders	Cost	Sales	Sales territory	Payments	Planning	Employee	Salaries	Facilities	Work in progress	Machine load	Open requirement	Shop floor routings	Product	Product design	Parts master	Bill of materials
Market analysis	R									R	R		R								R			
Product range review									R				R											
Sales forecasting	R	C								R	R		C								R			
Financial planning		R							R				C											
Capital acquisition		R	C										R											
Funds management		R	R																					
Product design													R								C	C	C	
Product pricing		R							R												C	R		
Product spec. maint.																					R		C	C
Materials requirements				R															C		R		R	R
Purchasing				C	C																R		R	
Receiving				R	R	R															R		R	
Inventory control						C											R							
Quality control					C																			
Capacity planning				R												R		C	R	R				
Plant scheduling																R	C	R		R	R			
Workflow layout																C				C	R			
Materials control				R													R				R			R
Sizing and cutting																		R		C	R			R
Machine operations																		R		C				
Territory management	C							R			R													
Selling										C	C													
Sales administration								R			R													
Customer relations	R							R		R														
Finished stock control							C										R				R			
Order servicing	R							C													R			
Packing								R													R			
Shipping																					R			
Creditors and debtors	R			R								R												
Cash flow	R			R	R			R	R			R			R		R							
Payroll												C		R	R									
Cost accounting					R				C			C												R
Budget planning		C	R						R	R			R				R							
Profitability analysis									R	R														
Personnel planning			R											C	C									
Recruiting														R	R									
Compensation policy			R											R	R									

Cartesian Product (Cross Product) of Databases And Processes [Martin Book II 1990.]; C= Create, R=Read, U= Update, D = Delete

	SUBJECT DATABASES																							
PROCESSES	Planning	Budget	Financial	Product	Product design	Parts master	Bill of materials	Open requirements	Vendor	Procurements	Materials inventory	Machine load	Work in progress	Facilities	Shop floor routings	Customer	Sales	Sales territory	Fin. goods inventory	Orders	Payments	Cost	Employee	Salaries
Market analysis	R			R												R	R	R						
Product range review	R																					R		
Sales forecasting	C	C		R												R	R	R						
Financial planning	C	R																				R		
Capital acquisition	R	R	C																					
Funds management		R	R																					
Product design	R			C	C	C																		
Product pricing		R		C	R																	R		
Product spec. maint.				R		C	C																	
Materials requirements				R		R	R	C	R															
Purchasing				R		R			C	C														
Receiving				R		R			R	R	R													
Inventory control											C		R											
Quality control										C														
Capacity planning								R	R			C		R	R									
Plant scheduling				R								R	C	R	R									
Workflow layout				R										C	C									
Materials control				R			R		R				R											
Sizing and cutting				R			R					R			C									
Machine operations												R			C									
Territory management																C		R		R				
Selling																	C	C						
Sales administration																		R		R				
Customer relations																R	R			R				
Finished stock control				R									R						C					
Order servicing				R												R				C				
Packing				R																R				
Shipping				R																				
Creditors and debtors									R							R					R			
Cash flow									R	R			R			R				R	R	R		R
Payroll																					C		R	R
Cost accounting							R			R											C	C		
Budget planning	R	C	R										R				R					R		
Profitability analysis																	R					R		
Personnel planning			R																				C	C
Recruiting																							R	R
Compensation policy			R																				R	R

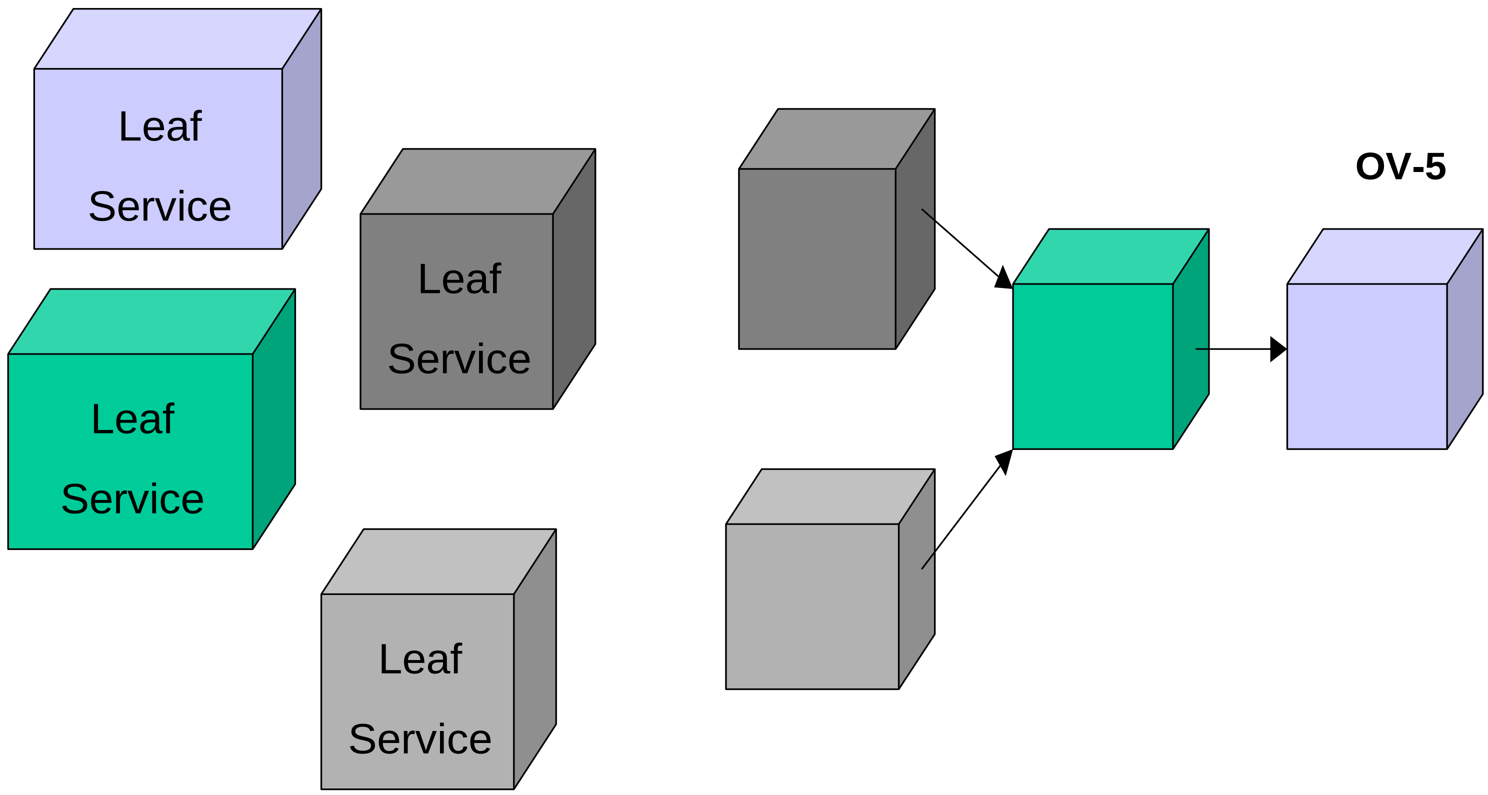
Partition of Databases and Processes Set Into Logical Functional Groupings Or Natural Business Areas, Data from Slide 35 [Martin Book II 1990; Gersting 1998.]; C= Create, R=Read, U= Update, D = Delete

	ENTITY TYPES															
LEAF ACTIVITIES	Employee	Contact Employee	Applicant	HR Compensation Regs, Plans, etc.	HR Benefits Regs & Plans	HR Staffing Requirements & Plans	Job Requisition	Stockholder	Boardmember	Misc. Contacts/VIPs	Financial Plans	Accounting Regs, Practices	Ledger Accounts	Customer Purchase Order/Invoice	Customer Payments	Other Invoice
Evaluate Financial Proposals																
Estimate Near - Term Earnings														R		
Prepare Budget	R	R		R	R						C	R	U			
Receive Funds												R		R	C	U
Pay Funds	R											R				
Report Finances	R											R	U	R	R	R
Administer Taxes												R	R		R	R
Maintain Financial Reg, Policies											R	U				
Audit Finances												R	R		R	R
Manage Financial Investments								C				R				
Plan Human Resources	R	R				U	U		R		R					
Acquire Personnel	C	C	C			R	R		U							
Position People in Jobs			R			R	U		R							
Terminate/Retire People	U	U							U							
Plan Career Paths	U			R	R	R										
Develop Skills/Motivation	U	U			R	R										
Manage Individual Emp Relations	U	U			R											
Manage Benefits Programs					C											
Comply with Govt HR Regulations	R			R												
Maintain HR Regs, Policies				C		C										

Cartesian Product (Cross Product) of Entity Types And Leaf Activities [Martin Book II 1990.] Note: The Last Two Natural Business Areas, Subsets 7 & 8 (From Slide 36) Are Used For Creating The Matrix. C= Create, R=Read, U= Update, D = Delete

LEAF ACTIVITIES	ENTITY TYPES: Financial Plans	Ledger Accounts	Customer Payments	Other Invoice	Accounting Regs, Practices	Stockholder	HR Staffing Requirements & Plans	Job Requisition	Contact Employee	Employee	Boardmember	Applicant	HR Benefits Regs & Plans	Misc. Contacts/MPs	Customer Purchase Order/Invoice	HR Compensation Regs, Plans, etc.
Evaluate Financial Proposals																
Estimate Near - Term Earnings															R	
Prepare Budget	C	U			R				R	R			R			R
Receive Funds			C	U	R										R	
Pay Funds					R					R						
Report Finances		U	R	R	R					R					R	
Administer Taxes		R	R	R	R											
Maintain Financial Reg, Policies	R				U											
Audit Finances		R	R	R	R											
Manage Financial Investments					R	C										
Plan Human Resources	R						U	U	R	R	R					
Acquire Personnel							R	R	C	C	U	C				
Position People in Jobs							R	U			R	R				
Terminate/Retire People									U	U	U					
Plan Career Paths							R			U			R			R
Develop Skills/Motivation							R		U	U			R			
Manage Individual Emp Relations									U	U			R			
Manage Benefits Programs													C			
Comply with Govt HR Regulations										R						R
Maintain HR Regs, Policies							C									C

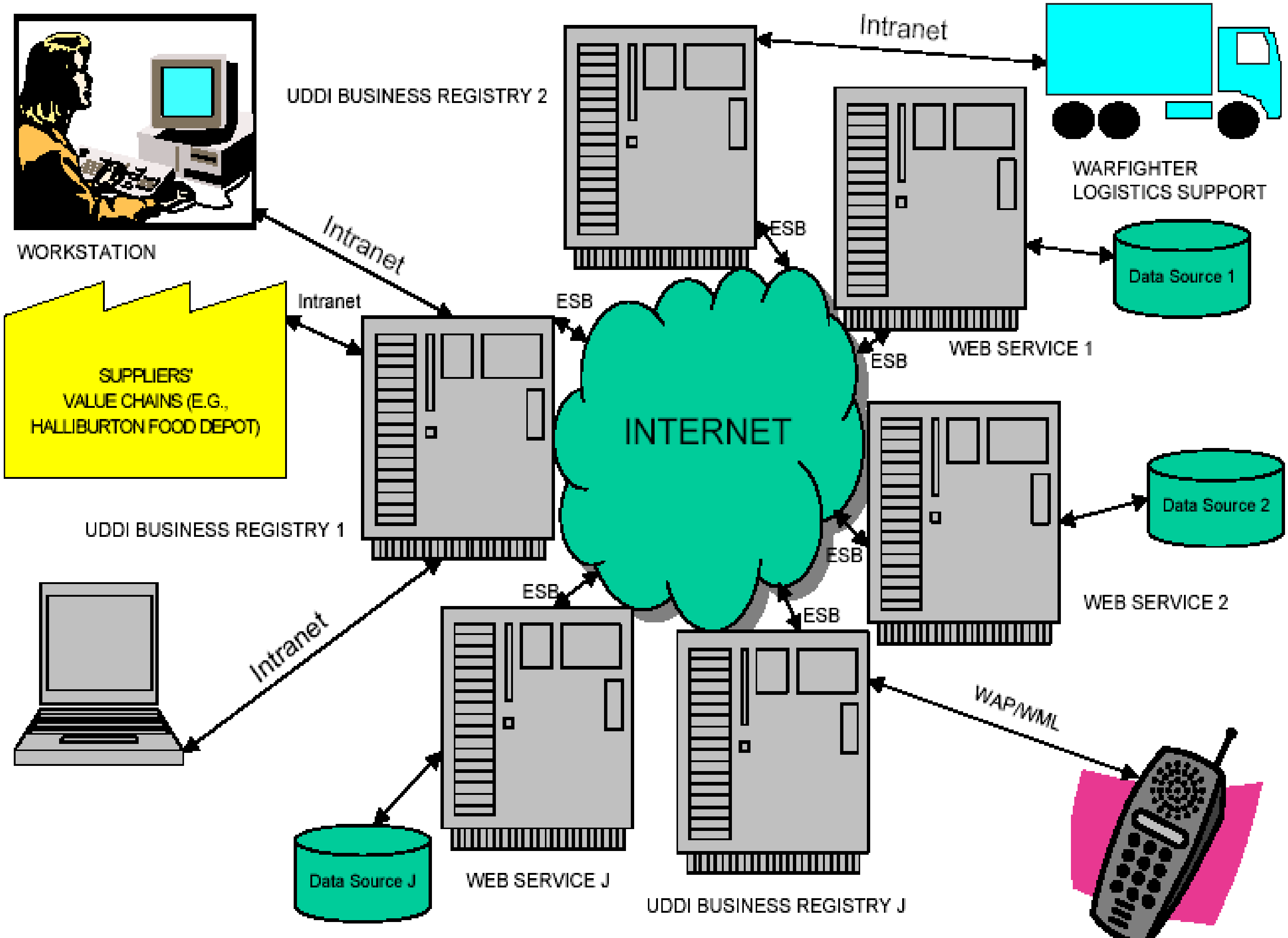
Partition Of Subsets (From Slide 36), Into Mutually Exclusive Subsets Of Leaf Activity-Entity Types Using The Cartesian Cross Product of Row And Column [Martin Book II 1990; Gersting 1998.]; C= Create, R=Read, U= Update, D = Delete



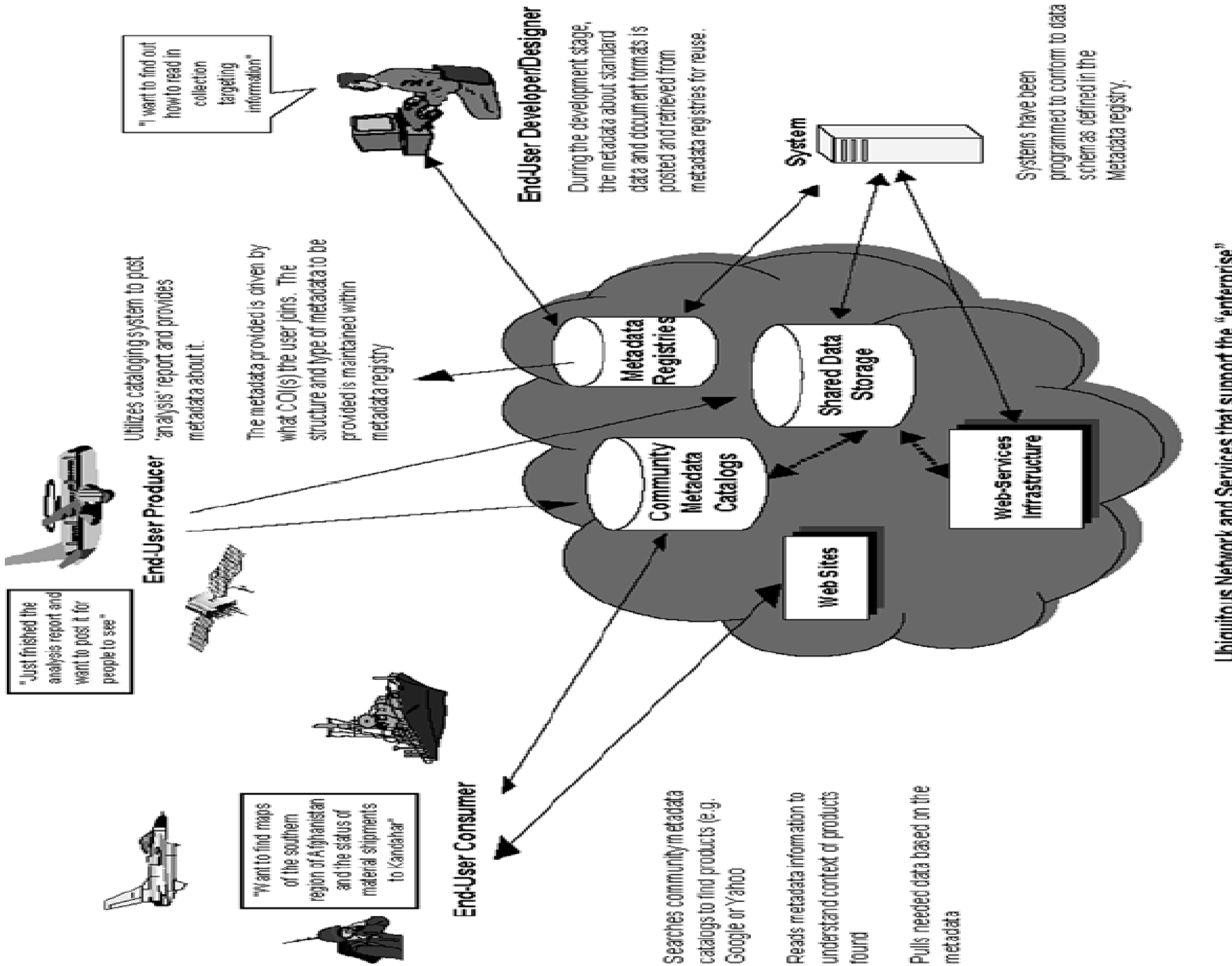
a. Leaf Services

b. Composition of Leaf Services

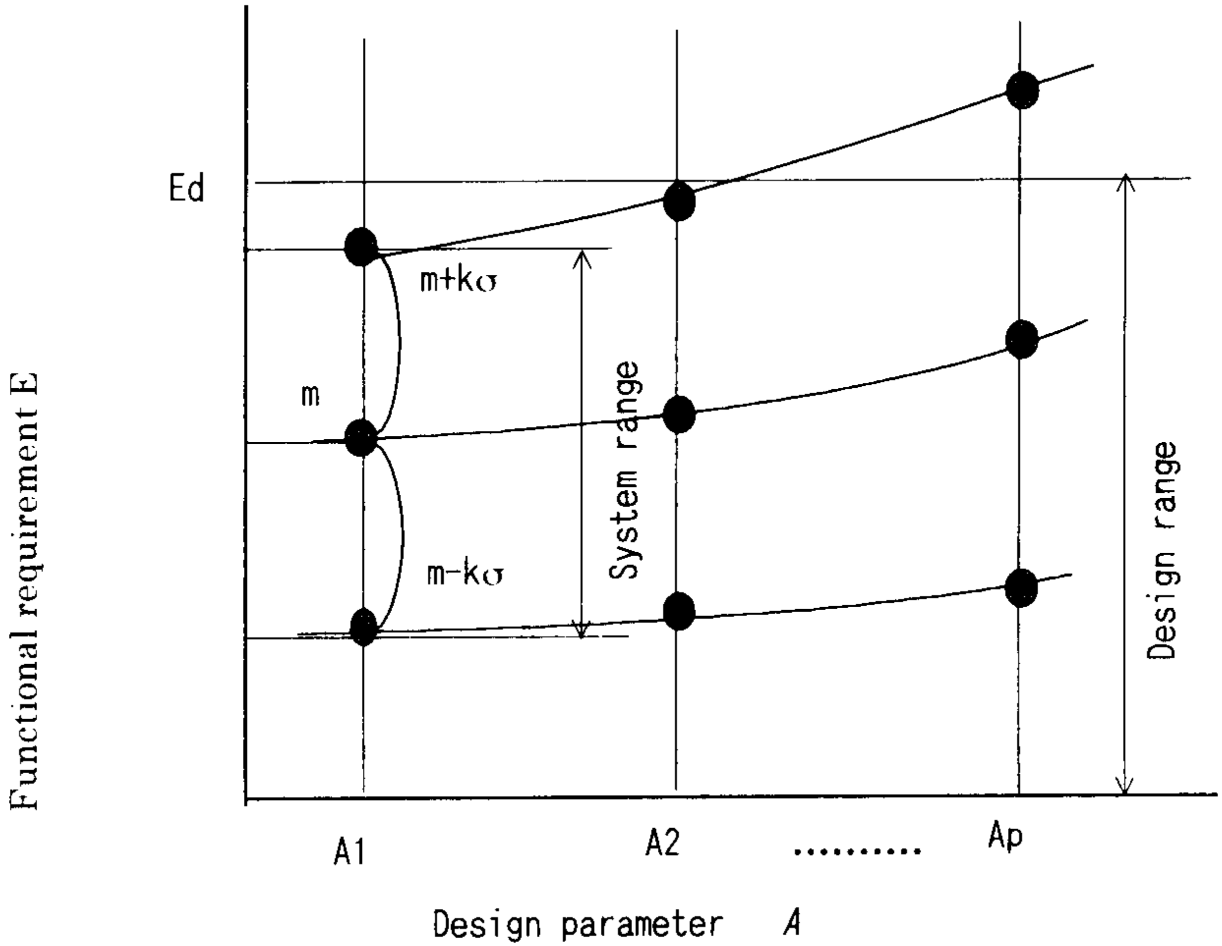
a). Creating Leaf Services, and b). Composition of Leaf Services to Create OV-5s.



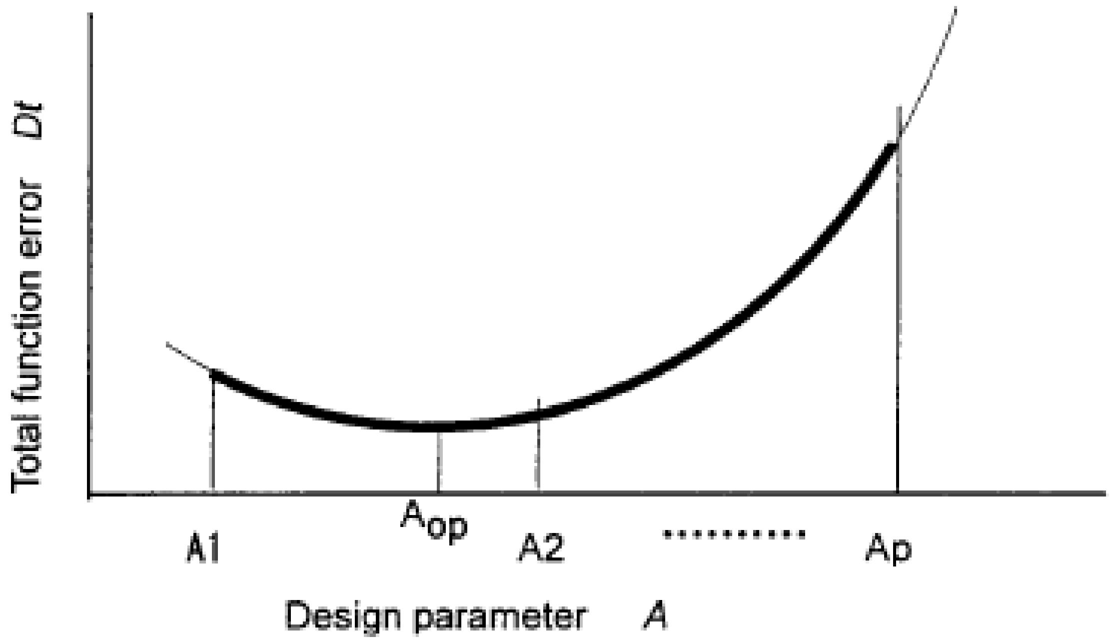
Service-Oriented Architecture (SOA) Model Of The Generic Integrated C4ISR SoS, An Updated Version of Nyamekye's Previous Work [Nyamekye June 2007.]



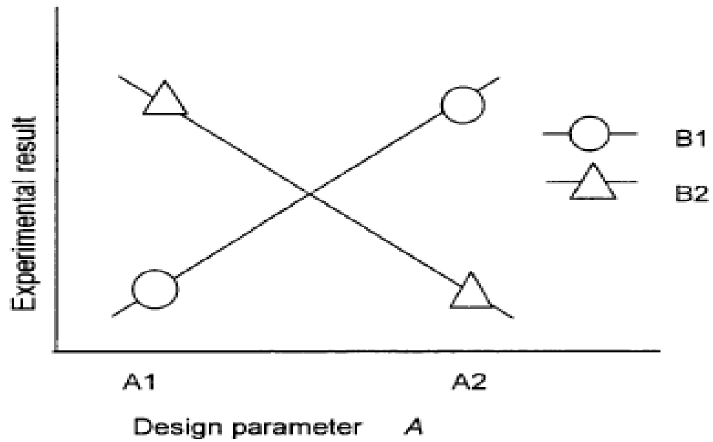
Compare an SOA blueprint for Global Information Grid (GIG) User Services by Alberts et al. [Alberts et al. 2003] with the previous diagram. They are very similar. In fact they proposed Power to the Edge principle to design Net-Centric Value Systems, but they did not provide any technical and scientific guidelines for doing so.



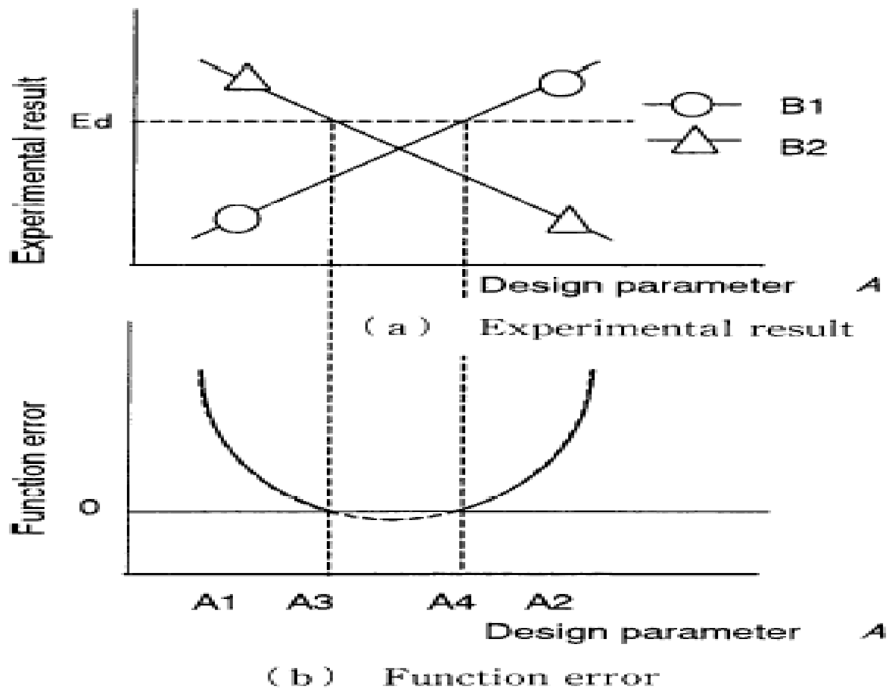
System Range of Design Parameter A for Functional Requirement [Nakazawa 2001.]



Total Information Content (Function Error Curve) [Nakazawa 2001.]



Experimental or Simulation Result For Functional Requirement, , With Interaction Factors [Nakazawa 2001.]



Information Content (Function Error Curve) for Functional Requirement, , [Nakazawa 2001.]

NO	DESIGN PARAMETERS (DPs)				EXPERIMENTAL OR SIMULATION RESULTS FOR FUNCTIONAL REQUIREMENTS (FRs)		
	A	B	C	D	E	F	G
1	A1	B1	C1	D1	E1	F1	G1
2	A1	B2	C2	D2	E2	F2	G2
3	A1	B3	C3	D3	E3	F3	G3
4	A2	B1	C1	D1	E1	F1	G1
5	A2	B2	C2	D2	E2	F2	G2
6	A2	B3	C3	D3	E3	F3	G3
7	A3	B1	C1	D1	E1	F1	G1
8	A3	B2	C2	D2	E2	F2	G2
9	A3	B3	C3	D3	E3	F3	G3

Orthogonal Table For Experimental or Simulation Design [Nakazawa 2001.]
DPs: Input Parameters in Equations 18, Network Classifications – Direct, Random, etc.
FRs: T_c (Equation 20)

Equation 18

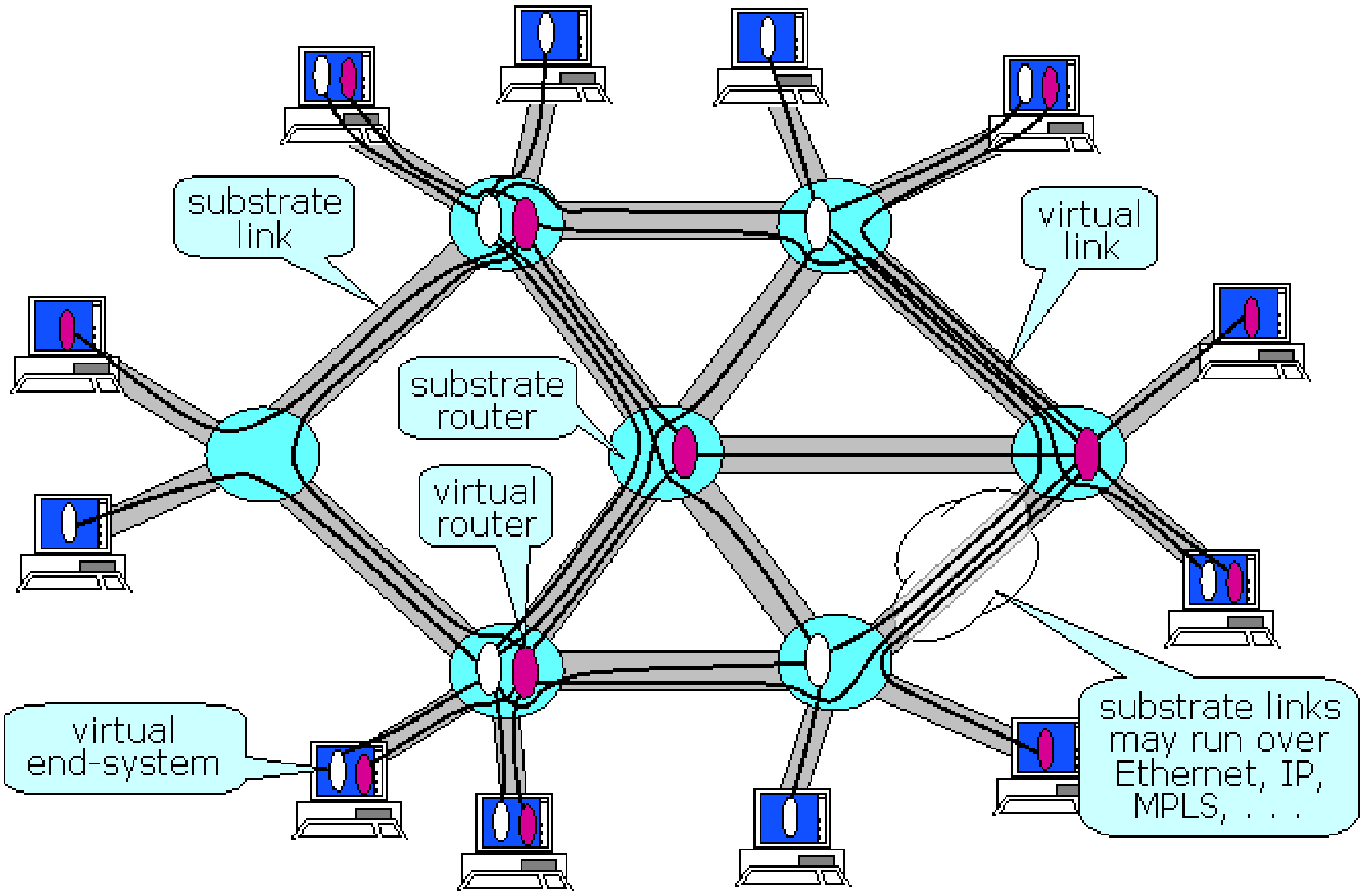
$$T = \frac{1}{\sigma_z}\left\{\prod_{r=1}^{\deg z}(1-K_r))^{\omega} r\right\} + \sum_{i=1}^{O}\frac{\lambda_i}{\gamma}\left[\frac{\frac{\lambda_i}{\mu' F_i}}{\mu' F_i - \lambda_i} + \frac{1}{\mu F_i} + \frac{L_i}{SP} + \frac{1}{\sigma_z}\left\{\prod_{r=1}^{\deg z}(1-K_r))^{\omega} r\right\}\right]$$

$$g(C) = \frac{e^{a+bC}}{1+e^{a+bC}} \qquad \text{Equation 19}$$

$$T_C = \frac{T}{1-g(C)} \qquad \text{Equation 20}$$

SERVICE-BASED SIMULATION MODELS AND EXPERIMENTAL TESTS

- Construct the Service-based Modeling and Simulation, Before Building a Prototype
- Use Organizational Simulation Concepts, Proposed by Rouse Et Al. [Rouse Et Al. 2005] to Capture Cognitive and Social Behaviors
- Use Meta-model Approach to Represent and Simulate Organizational Entities and the Relationships Among the Entities for the Service-based C4ISR SoS
- From the Service- Based Model, Use Intelligent Distributed Multi-agent-based System to Create Symmetric or Asymmetric Threat Tactics; Generate Behavior in a Simulation-based Training Environment; And Study the Effect of Information Overload on the Network Infrastructure (Equation 20), and the Cognitive and Social Behaviors of the Friendly Adversary and the Foes. Using Equation 20 and Design Navigation Method, Predict the Network Performance.
- To Create an Adaptive Network, We Can Use Corollary 1, and Use the Multi-agent Agent System to Dynamically Adjust the Network to Respond to Uncertainties Due to Information Overload. Using Corollary 1 to Design Intelligent Decouplers [Black 1991, Nyamekye 2005] That Can Provide Extra Bandwidths in the Network, Will Reduce Information Overload, and Thus Permit the Network to Dynamically Adjust Itself to Uncertainties.



In a virtualized network (intelligent decoupled network, Corollary 1), multiple *virtual networks* co-exist on top of a shared *substrate*. Different virtual networks provide alternate end-to-end packet delivery systems and may use different protocols and packet formats. Virtual networks are implemented by *virtual routers*, connected by *virtual links*.

http://www.arl.wustl.edu/netv/main.html

SUMMARY AND FUTURE POTENTIAL CAPABILITIES

The paper has discussed information content for adaptive network performance for C4ISR systems-of-systems using queuing theory and axiomatic design approach. Recent work by National Research Council (NRC) concludes that network research is an emerging scientific field. In fact, the definition of the technical terms for the network science is still unclear. Compounding this issue is the fact that the fundamental knowledge of networks is still primitive. Thus, the paper first discusses the network types and network classifications. Drawing on the previous author's work, the paper emphasizes that the axiomatic design, integrated with Service-Oriented Architecture-Based Department of Defense Architecture Framework (SOA)-Based DODAF, establishes the scientific framework for designing integrated C4ISR systems-of-systems (SOS), of which the network infrastructure is a subsystem. Borrowing Kleinrock's work on ARPANET, the detailed queuing models have been presented for the network performance. Furthermore, the information content from AXIOM 2 of axiomatic design is employed for the network optimization, including the effect of information overload, on the network performance for the Net-Centric SOS. The paper discusses that the Service-based simulation and experimental tests are needed to provide the data for the queuing models for network performance and optimization of the C4ISR SOS. The Design Navigation Method, proposed by Nakazawa has been discussed for experimental and simulation design, and for optimization, under scenarios of multi-functional requirements (FRs) and interaction effects among the design parameters (DPs). Using Corollary 1 to design intelligent decouplers that can provide extra bandwidths in the network, will reduce information overload, and thus permit the network to dynamically adjust itself to uncertainties. Such an integrated queuing modeling and axiomatic design approach, is critical for not only designing and operating complex civil-military endeavors, but also it is critical for creating a test bed for designing information-based distributed enterprise systems for counter-terrorism and natural disasters such as Katrina for the Department of Homeland Security. The paper also establishes the scientific framework for research and development in cognitive and social domains for the individual, unit, and organizational behavior within the context of complex network environments.

QUESTIONS???