



Air Force Institute of Technology



Extending Net-Centric Quality of Service to Systems of Systems

12th Annual NDIA Systems Engineering Conference
San Diego, CA 26-29 October 2009

Major Vinod Naga, USAF
Systems Engineering PhD Student
Air Force Institute of Technology
Wright Patterson AFB, OH





Outline

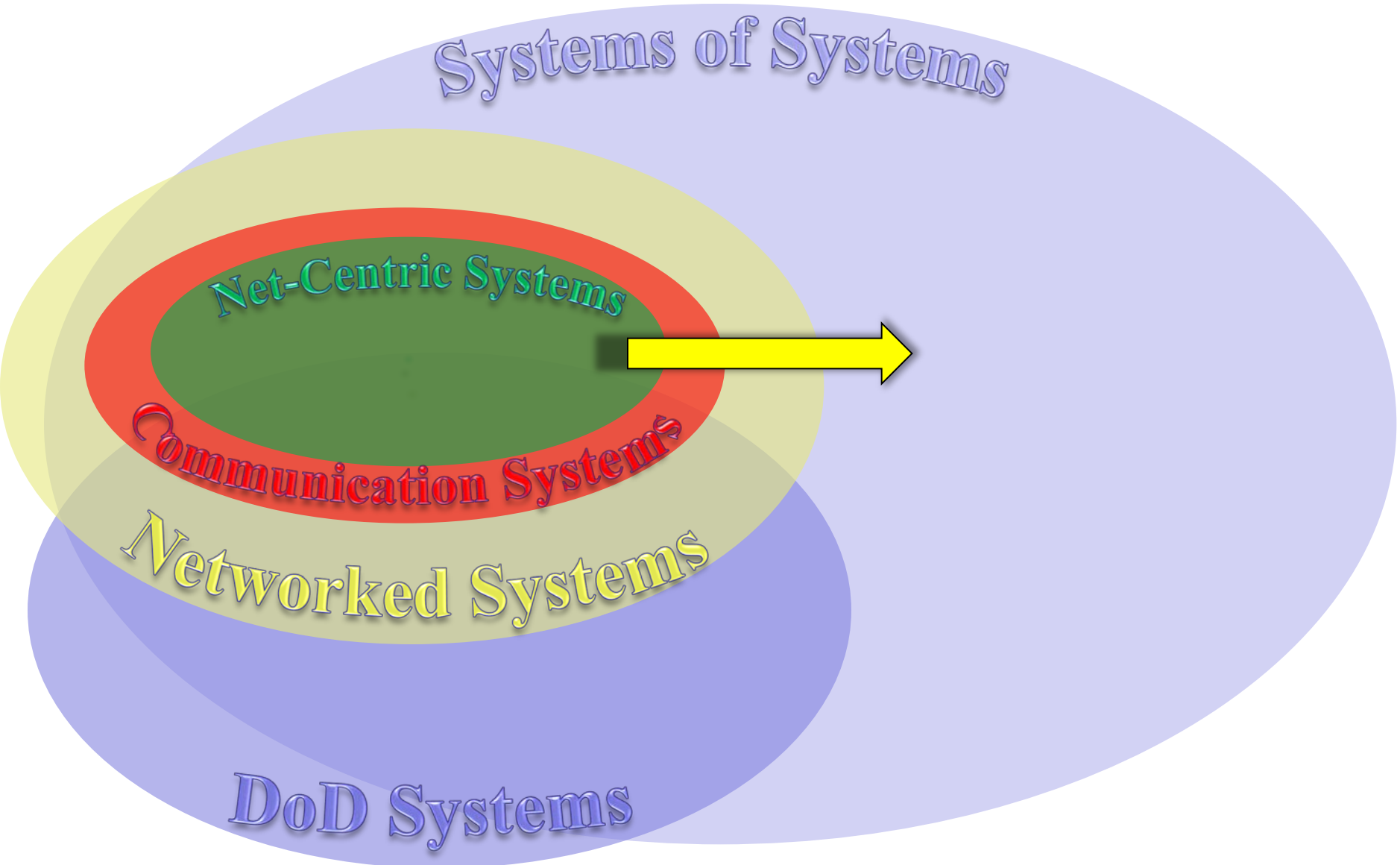


Offer an alternative perspective to viewing interactions within systems of systems based upon a net-centric quality of service framework.

- Quality of Service (QoS)
- Systems of Systems (SoS) Abstract
- QoS in Net-Centric Systems
- Key QoS Features
- QoS in Generalized SoS
- Improving the SoS
- SoS Necessities
- Systems Engineer Perspective
- QoS Construct for the SoS



QoS for SoS





Quality of Service



- Resource reservations
- Priority for apps, users, data flows
- Specific performance
- vs. best-effort and over-provisioning
- Service Level Agreement (SLA)
- Monitored, maintained, managed
 - QoS may refer to the measure
 - Intserv – per flow (RSVP)
 - Diffserv – per class (DSCP)
 - Traffic Shaping and Scheduling techniques
- Device capability
- Service-Oriented Architecture (SOA) view



- Resource Reservation
- How Signaling Transferred
- Coupling with Routing/Forwarding Method
- State of Resource Management
- Required Participation



QoS Key Parameters Example (1 of 2)



RSVP: - reservation-based QoS protocol
- based on integrated services (INTSERV) model

Key Feature	Implementation
Resource Reservation	<p>Class</p> <ul style="list-style-type: none">• best-effort• rate-sensitive• delay sensitive <p>Assignment</p> <ul style="list-style-type: none">• distinct (per flow)• shared (group)
How Signaling Transferred	<p>Messages</p> <ul style="list-style-type: none">• reservation-request• path• error/confirm• teardown <p>Communicants</p> <ul style="list-style-type: none">• host-to-router• router-to-router <p>Maintenance</p> <ul style="list-style-type: none">• refreshed• times out



QoS Key Parameters Example (2 of 2)



RSVP: - reservation-based QoS protocol
- based on integrated services (INTSERV) model

Key Feature	Implementation
Routing Coupling	Routing Independent
Resource Management State	Soft in all nodes
Required Participation	Clusters – tunneling possible



Origins and Directions



- **SERVQUAL:** - developed by Zeithaml, Parasuraman, Berry
 - measure how service organizations meet customer needs
- **QoS:** maintaining circuit-switched telephony – transitioned to IP QoS.
- **QoE:** user perception of product quality and utility.

Service Quality SERVQUAL	Quality of Service QoS	Quality of Experience QoE
<ul style="list-style-type: none">▪ Tangibles▪ Reliability▪ Responsiveness▪ Competence▪ Courtesy▪ Credibility▪ Feel Secure▪ Access▪ Communication▪ Understanding the Customer	<ul style="list-style-type: none">▪ Delay▪ Jitter▪ Dropped Packet Rate▪ Packet Error Rate▪ Throughput	<ul style="list-style-type: none">▪ Usefulness▪ Happiness▪ Satisfaction▪ Worthwhile▪ Expected



System of Systems



a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities [Defense Acquisition Guidebook Ch. 4 "System of Systems Engineering"]

- Characteristics
 - Operational Independence SOA QoS
 - Managerial independence SOA QoS
 - Evolutionary development SOA QoS
 - Emergent behavior SOA QoS
 - Geographic distribution SOA QoS
- Control [Maier 1998]
 - Directed
 - Collaborative
 - Virtual
 - Acknowledged
- Examples
 - Aerospace Operations Center (AOC)
 - Air Traffic Control Systems
 - Public Utilities
 - Supply Chains



System of Systems



- Architecture
- Evolution and complexity
- Evolutionary architectures require: [Selberg & Austin, INCOSE 2008]
 - Standard interfaces
 - Interface layers
 - Continual system verification and validation
- Self-organized SoS [Bak Tang Wiesenfeld 1987]
- SoS may grow scale-free [Albert Jeong Barabasi 2000]
 - Hierarchical
 - Non-exclusive interdependencies
 - Fault tolerant

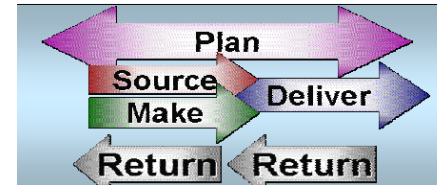


Supply Chain as a SoS



- DoD Supply Chain as a System of Systems [LTG Christianson (J-4) 26Jul06]

- Objective: Timely & Precise Response
 - Speed
 - Reliability
 - Visibility
 - Efficiency
 - Performance Tracking
 - Process Diagnosis
- Independent Players: Same Team, Dispersed, Complex, Resource Pressures

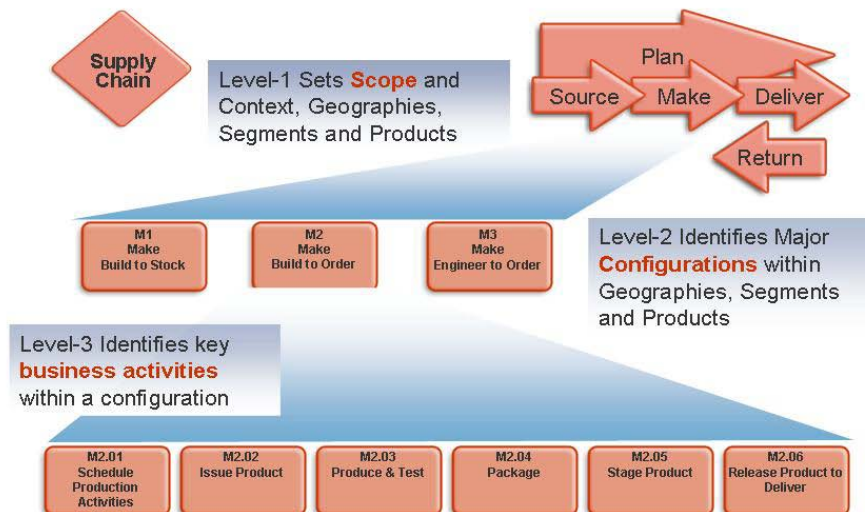


- Supply Chain Reference Model (SCOR) – Supply Chain Council

- sequencing
- elements of functional decomposition

SCOR Framework Levels

SCOR[®]
Supply Chain Council





Value of QoS for Net-Centric Systems



- Timely Data
- Design Service Levels
 - Specific Applications
 - Specific Users
 - Classes
- Designate and Maintain
 - Command and Control
 - Communications
- Preserve Scarce Resources
- Enable Cloud-Computing and SOA-Type Processes
 - Reduced forward footprint and resources
 - Centralized storage/processing
 - Minimize secondary methods
- Requirements
 - Efficient Routing
 - Control Signaling
 - Message Marking
 - Admission Policy
 - Admission Control

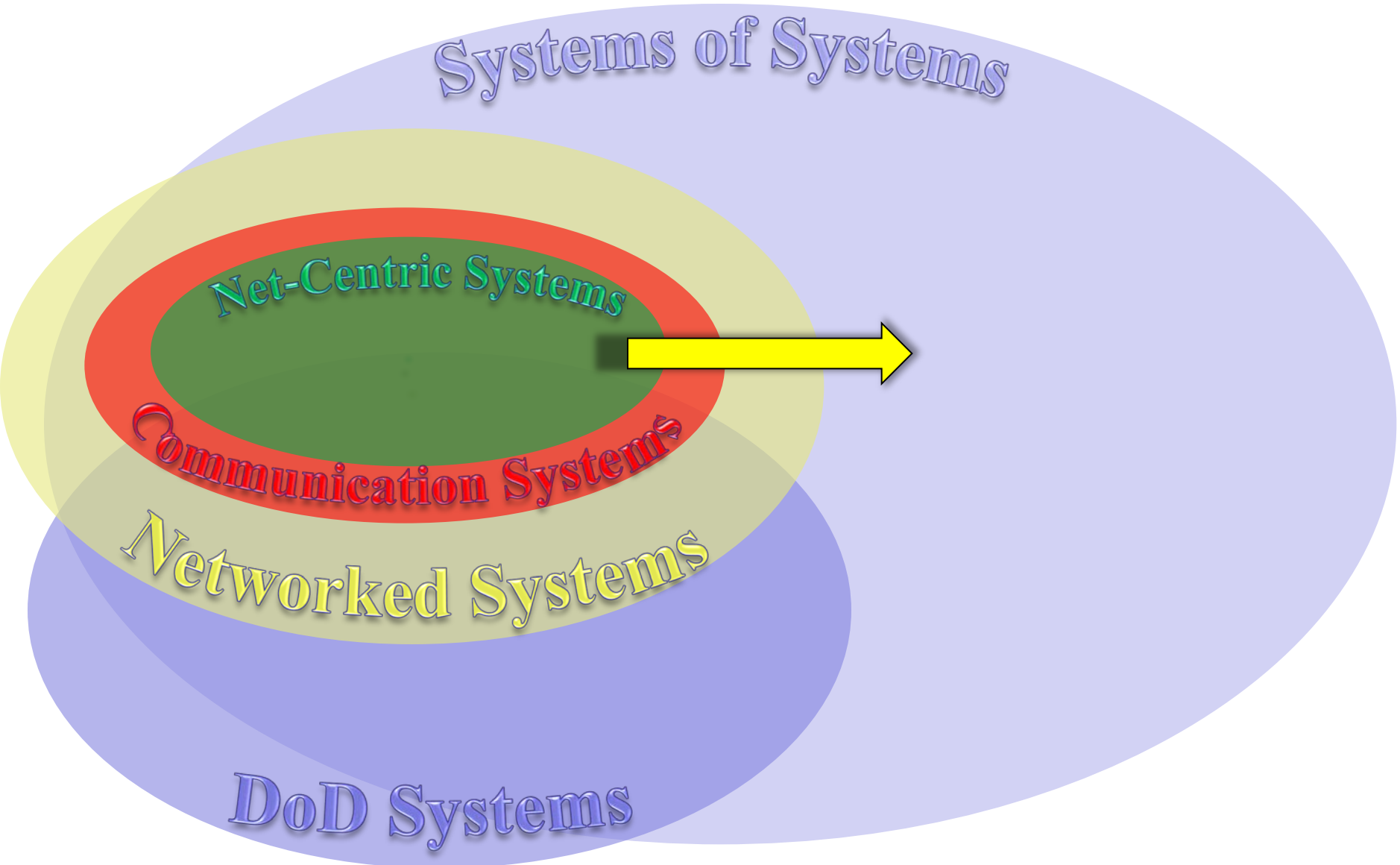


Key Features Delivered by QoS





QoS for SoS





QoS in a Generalized SoS



Key Feature	Implementation	Discussion
Resource Reservation	Priority, responsiveness, quality, detail, precision... distinct or shared	Heavily Application Dependent
How Signaling Transferred	<ul style="list-style-type: none">• request-for-bids, RFP, proposal, contract, kickoff, reviews, wrapup• non-disclosure-agreement• advertisement, menu, subscription, publish, instructions, terminate	contract, PO, warranty, maintenance SLA, contract, PO, warranty, maintenance
Routing Coupling	Closely or loosely coupled	CBD, sub-contract, invitation to bid
Resource Management State	Soft or Hard one, some or none	IDIQ or FFP/pre-paid
Required Participation	Clusters – tunneling possible	Agreements form communities



Improvements to the SoS



- Managing with greater fidelity
 - Own resources
 - Promises
- Systems leverage other systems
 - Reliability
 - Confidence
 - Risk
- Layered management of complexity
 - Framework
 - Emergence
 - Guarantees
- Outsourcing and core expertise
 - High cohesion
 - Purpose
 - Modularity (low coupling)



Requirements for QoS in SoS



Requirements for QoS in Net-Centric SoS

- Efficient Routing
- Control Signaling
- Message Marking
- Admission Policy
- Admission Control

Similarly...

- Efficient product delivery
- Vehicles
 - initiate
 - terminate
 - adjust
 - modify
- Labeling (ID and Priority)
- Admission criteria
- Triage at each node



QoS for SoS vs SERVQUAL



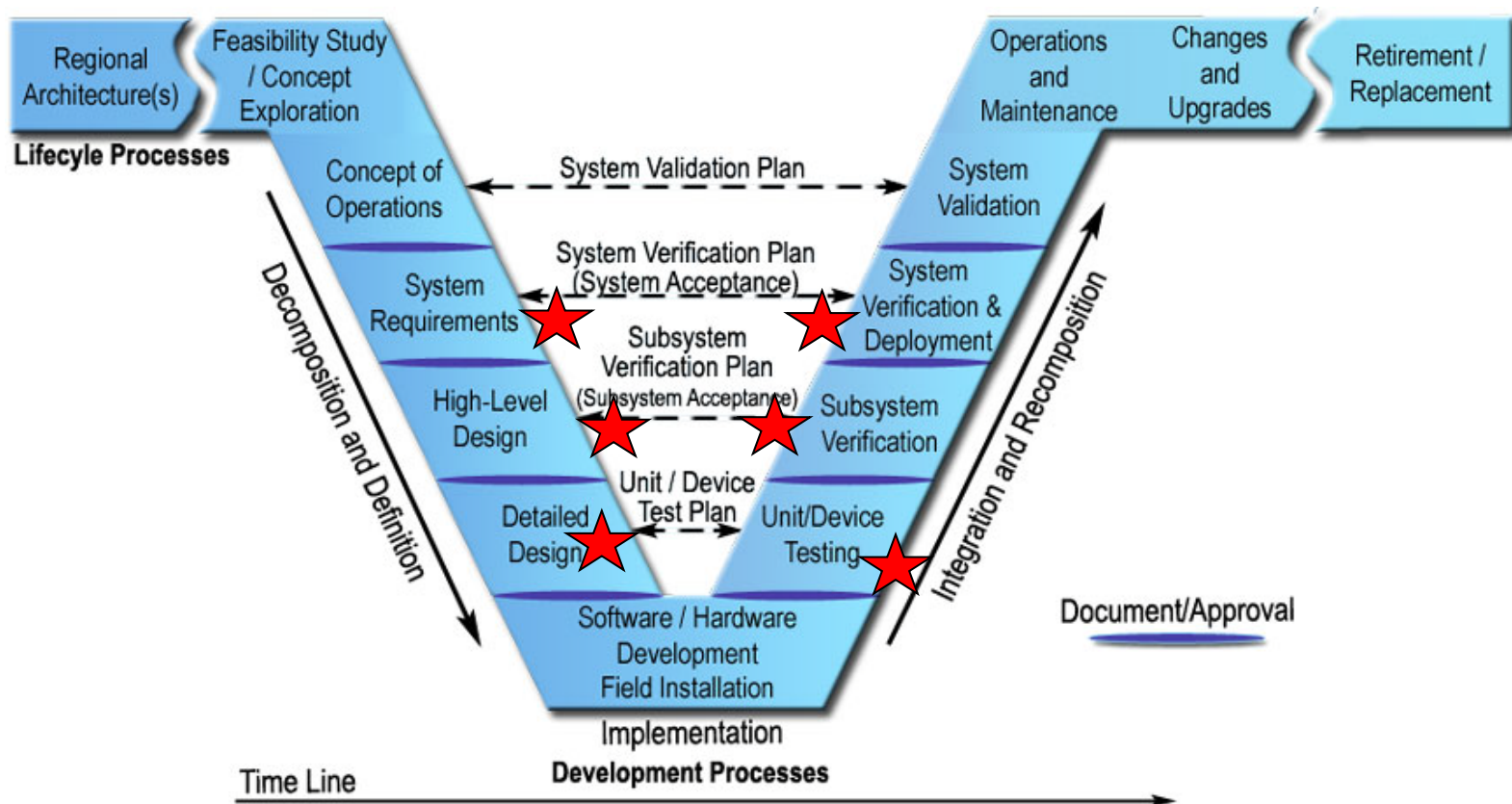
- SERVQUAL measured organization performance relative to customer needs
- QoS
 - Establish contract
 - Maintain commensurate flows
 - Means to adjust flows
- Automation in SoS
 - More common today
 - Measurement and control common
 - Feedback possible
- QoS for SoS requires
 - Documenting requirements
 - Monitor requirements fulfillment
 - Intermediates: divide and apply resources



Systems Engineering Motivation



- SoS Design and Build difficult undertaking
- QoS: critical and responsive
- QoS for SoS in “V” highlighted ★





System Engineering for System of Systems: Core Elements

- Translating Capability Objectives
- Understanding Systems and Relationships
- Assessing Performance to Capability Objectives
- Developing and Evolving an SoS Architecture
- Monitoring and Assessing Changes
- Addressing Requirements and Solution Options
- Orchestrating Upgrades to SoS

- Systems Engineering Guide for Systems of Systems 2008



Summary



- The Quality of Service (QoS) framework has promise to aid in design and operation of a System of System (SoS) which must allocate scarce resources.
- The SoS must include certain basic elements to gain from a QoS framework.
- SoS using a Service Oriented Architecture (SOA) are most compatible--any SoS may adopt the framework.



Contact



Major Vinod D. Naga, USAF

PhD Student

Air Force Institute of Technology

Department of Systems and Engineering Management

vinod.naga@us.af.mil

937-255-3636 x7126