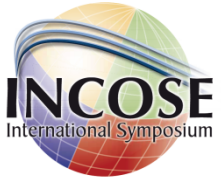
Air Force Institute of Technology



Effecting Quality of Service Across Systems of Systems

20th INCOSE International Symposium
Chicago, IL July 11-15, 2010

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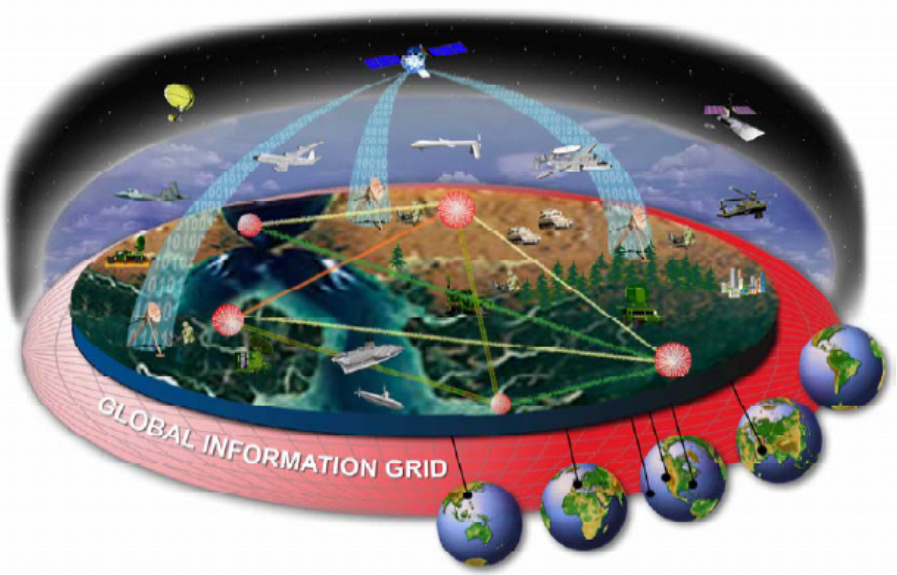
sponsored by Air Force Research Laboratory Information Directorate, Rome, NY

Outline

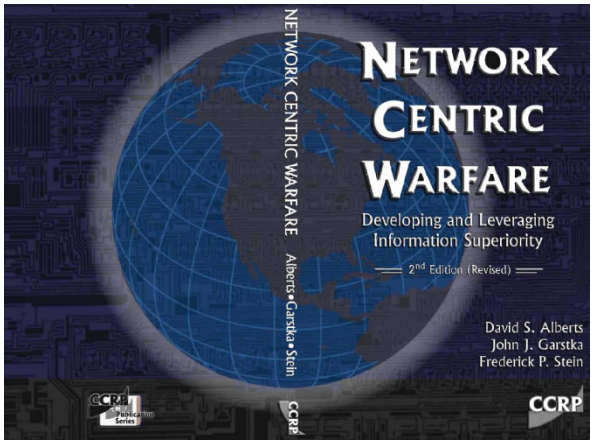
Focus on decomposition of missions followed by network resource allocation through Quality of Service (QoS) methods.

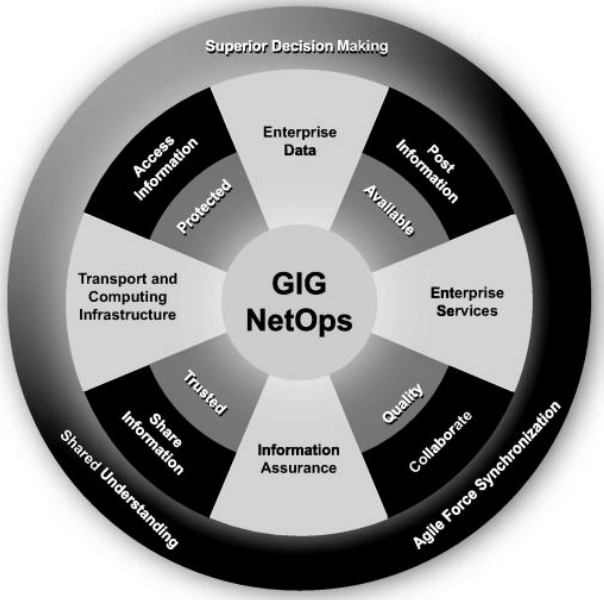


- Net-Centric Operations
- Mission Organization and Decomposition
- Quality of Service (QoS)
- Mission-Oriented QoS Performance
- Mission-Oriented QoS Experiment
  - Setup
  - Performance Requirements
  - Value
- Next Steps
- Summary

"…possibly the single-most transforming thing in our forces will not be a weapons system, but a set of interconnections and a substantially enhanced capability because of that awareness."
Former U.S. Secretary of Defense, Donald Rumsfeld

Network Centric Operations





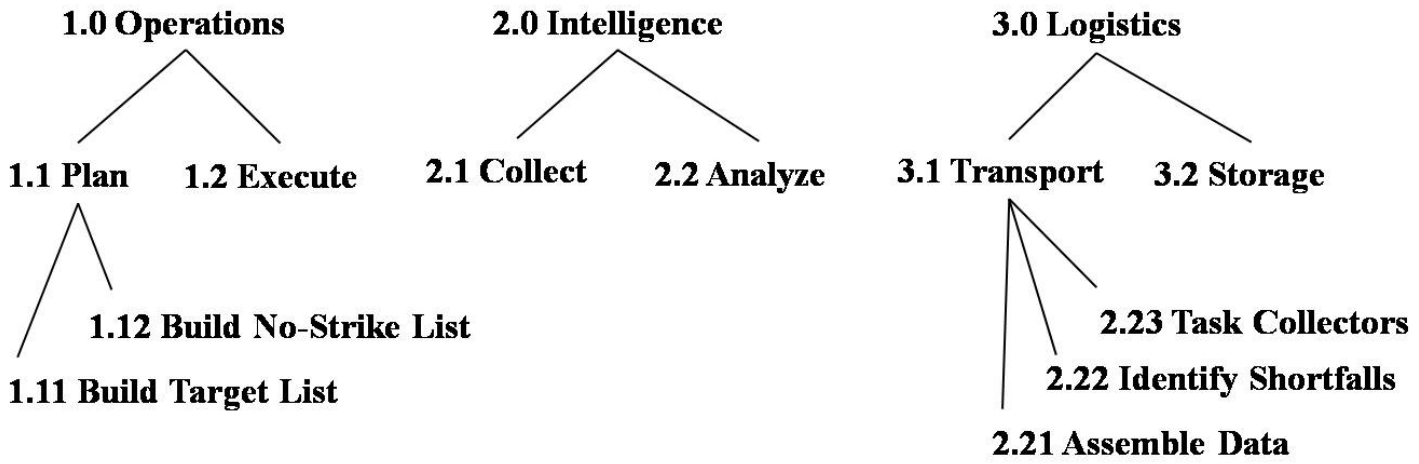
- Network Centric Warfare
- Global Information Grid
- Systems of Systems
- Interdependencies
- Publish-Subscribe
- Available Services to Diversity of Users

Battlefield Airborne Communications Node (BACN)
http://en.wikipedia.org/wiki/Battlefield_Airborne_Communications_Node

Mission Organization and Decomposition

Mission	Submission	SubSubmission
Operations		
Operations	Plan	
Operations	Plan	Build Target List
Operations	Plan	Build No-Strike List
Intelligence		
Intelligence	Collection	
Intelligence	Collection	Build Collection Plan
Intelligence	Analysis	
Intelligence	Analysis	Assemble Data
Intelligence	Analysis	Identify Shortfalls
Intelligence	Analysis	Task Collectors
Logistics		
Logistics	Transportation	
Logistics	Storage	

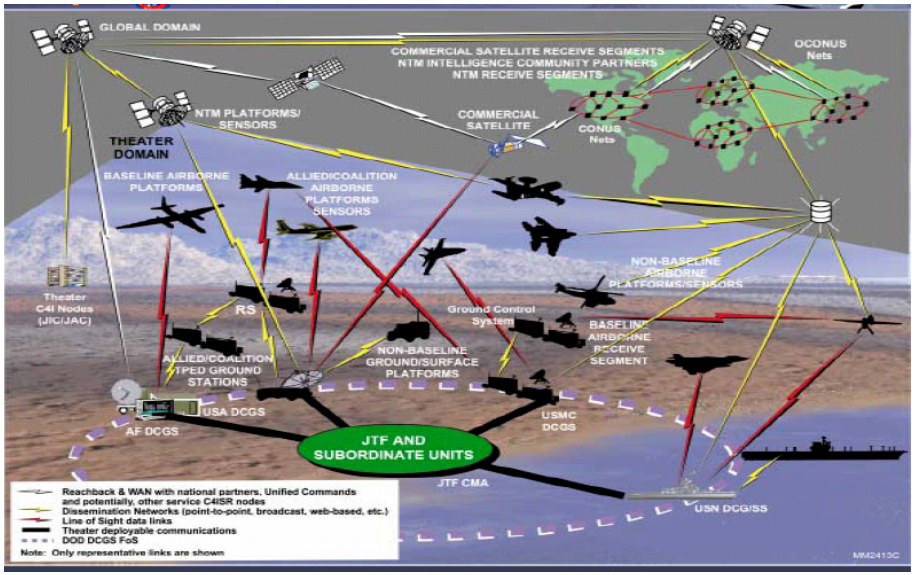
- Functional Allocation
- Complex Activities
- Organizational Relationship
- Method for Strategy to Task



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 or the method
  - Intserv – per flow (RSVP)
  - Diffserv – per class (DSCP)
  - Traffic Shaping and Scheduling techniques
- Device capability
- Service-Oriented Architecture (SOA) view

Quality of Service Design Parameters



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

QoS Design Parameters Ex. (1 of 2)

DSCP: - class-based QoS protocol
- based on differentiated services (DIFFSERV) model

Key Parameters	Implementation
Resource Reservation	Class • best-effort • assured-forward & drop priority • expedited forwarding Assignment • distinct (to meet committed access rate) • shared (group)
How Signaling Transferred	Header • Type of Service (ToS) • DiffServe (DS) field Communicants • originator & destination • Intermediates for per-hop Maintenance • queued by class • weighted queues • class-based policing • metering

http://www.cisco.com/en/US/tech/tk543/tk757/technologies_tech_note09186a00800949f2.shtml

QoS Design Parameters Ex. (2 of 2)

DSCP: - class-based QoS protocol
- based on differentiated services (DIFFSERV) model

Key Parameters	Implementation
Routing Coupling	Per-Hop Behavior in DSCP class
Resource Management State	Soft in all nodes, random early detection, congestion avoidance
Required Participation	None – but need all nodes in path for performance assurances

http://www.cisco.com/en/US/tech/tk543/tk757/technologies_tech_note09186a00800949f2.shtml

Origins and Directions

- SERVQUAL: - developed by Zeithaml, Parasuraman, Berry
  - measure how service organizations meet customer needs

Mission-Oriented QoS

- 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 Experience QoE	Quality of Service QoS
▪ Tangibles ▪ Reliability ▪ Responsiveness ▪ Competence ▪ Courtesy ▪ Credibility ▪ Feel Secure ▪ Access ▪ Communication ▪ Understanding the Customer	▪ Usefulness ▪ Happiness ▪ Satisfaction ▪ Worthwhile ▪ Expected	▪ Delay ▪ Jitter ▪ Dropped Packet Rate ▪ Packet Error Rate ▪ Throughput

Mission-Oriented QoS

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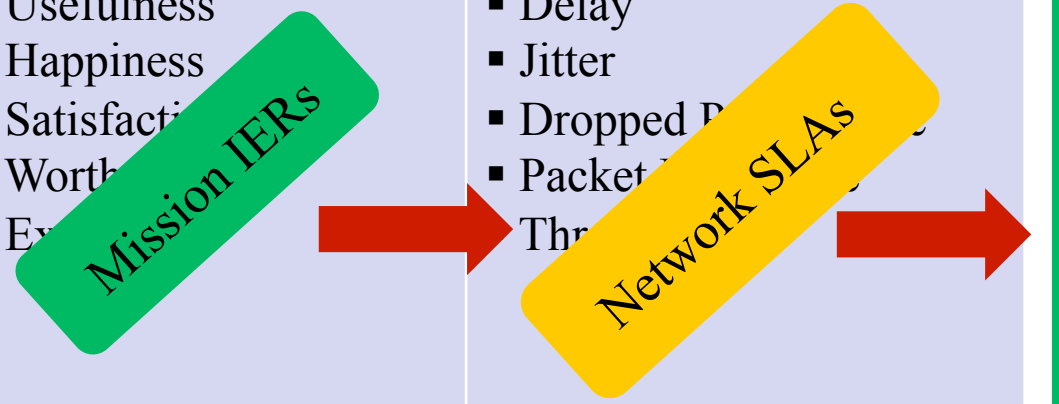

Mission-Oriented QoS

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Mission-Oriented QoS

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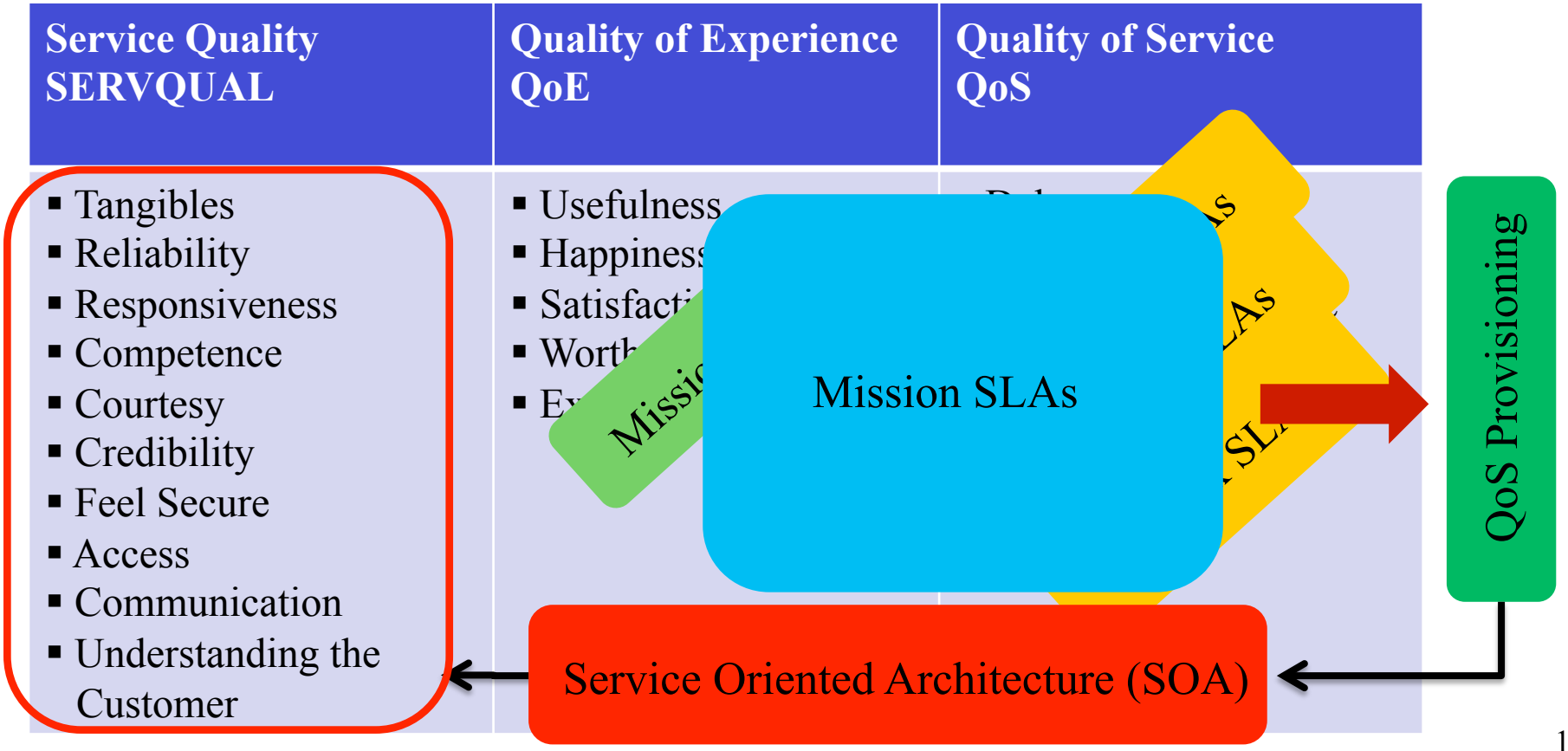
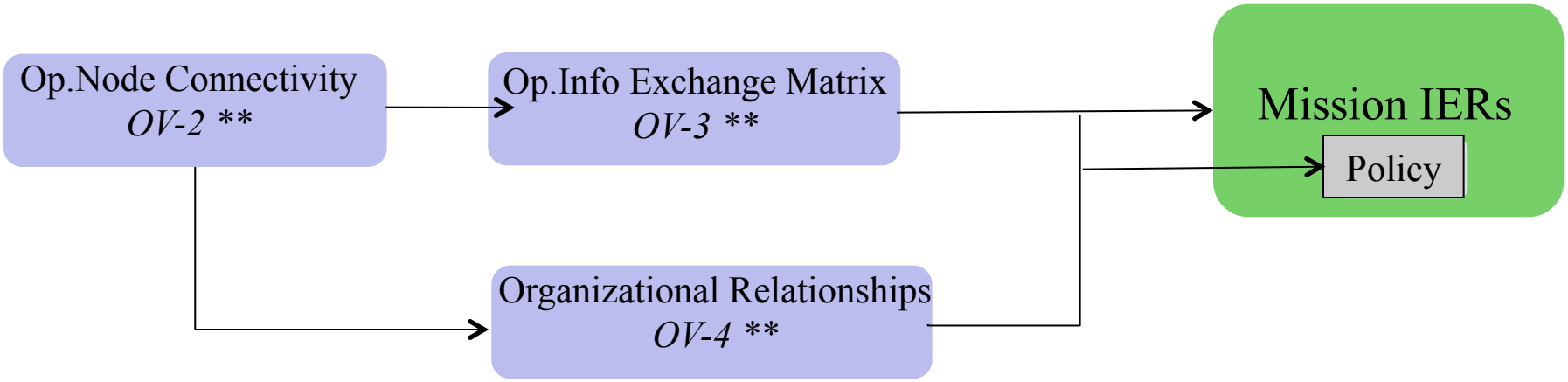


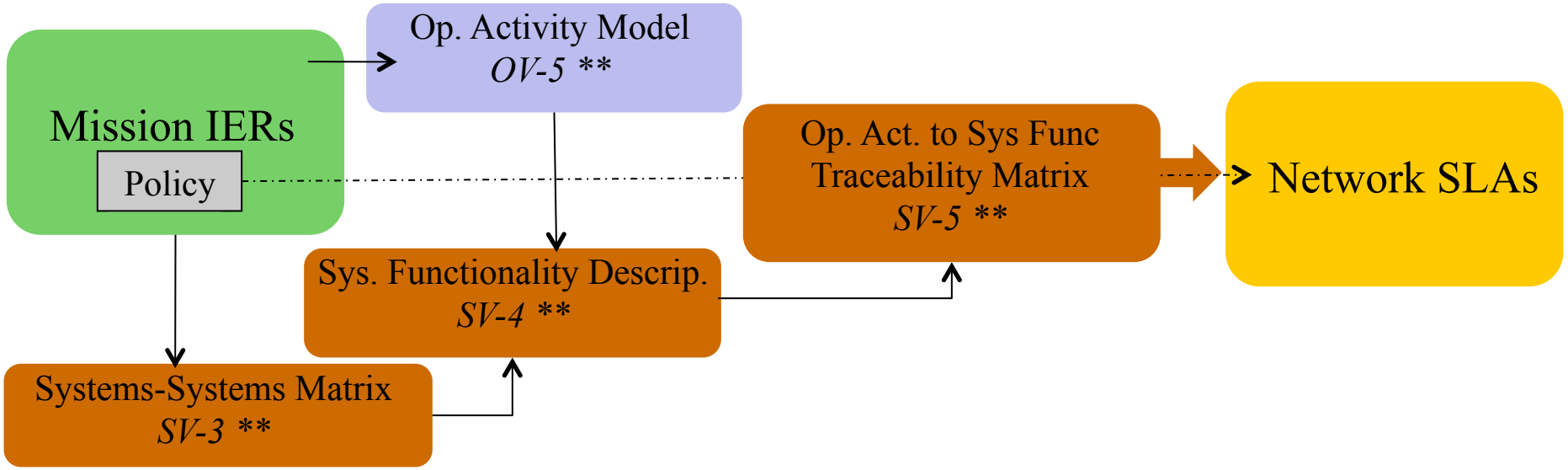
Mission to QoS Process



- Mission IERs: Operational information exchanges combined with organizational relationships
- Operating policies yield policies for moving information for missions

** DoD Architecture Framework v2.0 views

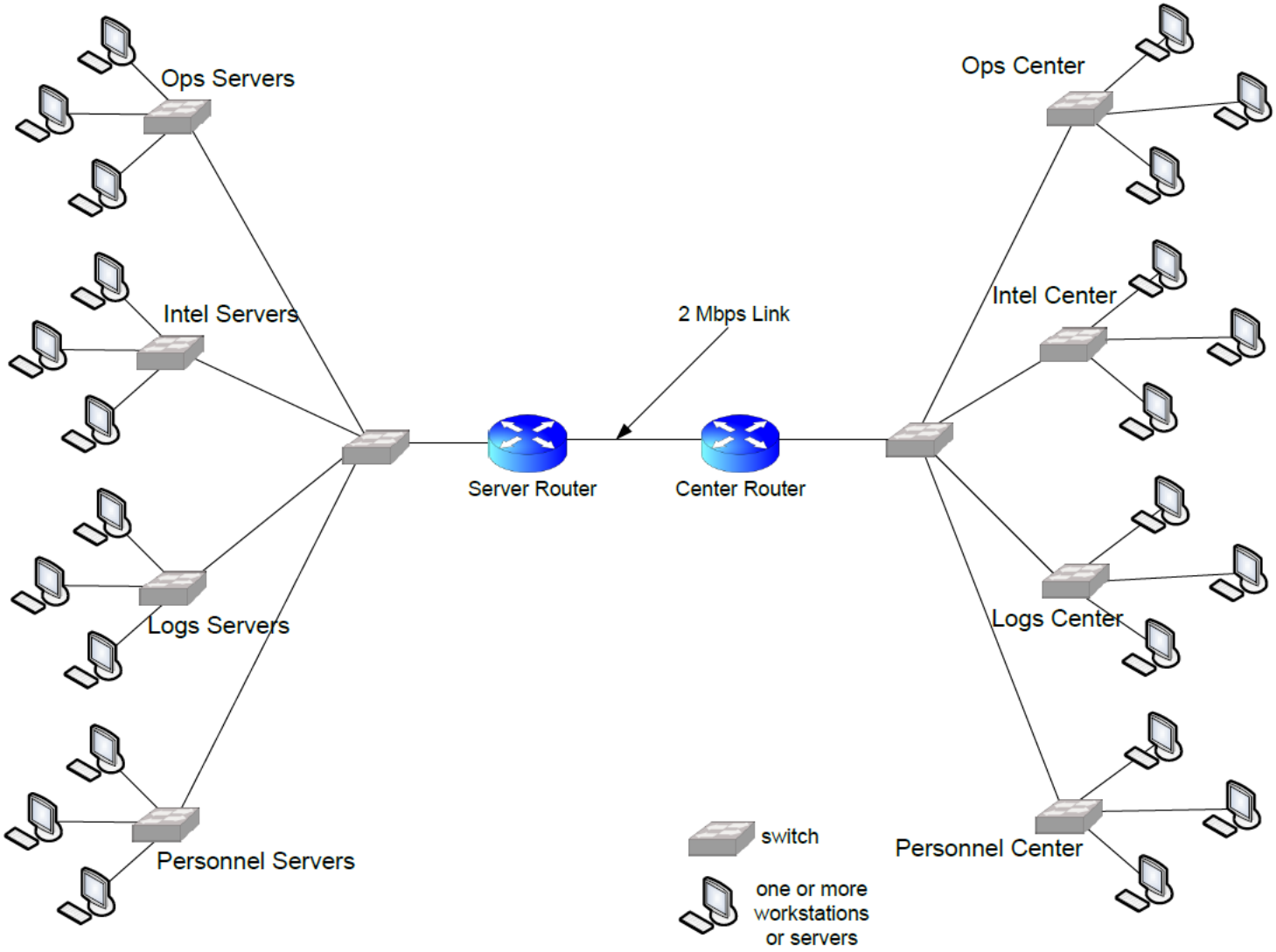
Mission to QoS Process



- Systems planning
  - tracing missions to functions to systems
- Supported by systems architecture work
- Allow mission IERs to define Network SLAs

** DoD Architecture Framework v2.0 views

Demonstrate Improved Network Performance with Mission-Oriented QoS



Campaign Phases

Campaign Phase:	Equal	Logistics	Operations	Intelligence
Priority 1		Logs	Ops	Intel
Priority 2	All Mission Areas	Intel	Intel	Ops
Priority 3		Ops	Logs	Logs
Priority 4		Personnel	Personnel	Personnel

Priorities of Mission Areas for each Campaign Phase

IER Requirements

Campaign Phase:	Equal	Logistics	Operations	Intelligence
Priority 1		Logs	Ops	Intel
Priority 2	All Mission Areas	Intel	Intel	Ops
Priority 3		Ops	Logs	Logs
Priority 4		Personnel	Personnel	Personnel

Priorities of Mission Areas for each Campaign Phase

Campaign Phase:	Equal	Logistics	Operations	Intelligence
IER 1	Ops traffic: 300 kbps	Pre-combat logistical staging	Ops command and control	Streaming ISR feeds
IER 2	Intel traffic: 300 kbps	Real-time intel updates	Real-time intel updates	Ops command and control
IER 3	Logs traffic: 300 kbps	Pre-staging ops plans	Ops support logistics	Ops support logistics
IER 4	Pers traffic: 300 kbps	Health and wellness info	Health and wellness info	Health and wellness info

Information Exchange Requirements for each Campaign Phase

SLA for Phases

Campaign Phase:	Equal	Logistics	Operations	Intelligence
Priority 1		Logs	Ops	Intel
Priority 2	All Mission Areas	Intel	Intel	Ops
Priority 3		Ops	Logs	Logs
Priority 4		Personnel	Personnel	Personnel

Priorities of Mission Areas for each Campaign Phase

Campaign Phase:	Equal	Logistics	Operations	Intelligence
IER 1	Ops traffic: 300 kbps	Pre-combat logistical staging	Ops command and control	Streaming ISR feeds
IER 2	Intel traffic: 300 kbps	Real-time intel updates	Real-time intel updates	Ops command and control
IER 3	Logs traffic: 300 kbps	Pre-staging ops plans	Ops support logistics	Ops support logistics
IER 4	Pers traffic: 300 kbps	Health and wellness info	Health and wellness info	Health and wellness info

Information Exchange Requirements for each Campaign Phase

Campaign Phase:	Equal	Logistics	Operations	Intelligence
SLS1	Ops traffic: 300 kbps	Logs End-to-End delay < 0.1 sec	Ops E-to-E delay < 0.1 sec	Intel E-to-E delay < 0.1 sec
SLS2	Intel traffic: 300 kbps	Logs traffic received > 95%	Ops pkt delay variance < 0.2	Intel pkt delay variance < 0.1
SLS3	Logs traffic: 300 kbps	Ops End-to-End delay < 0.3 sec	Ops traffic received > 99%	Intel traffic received > 99%
SLS4	Pers traffic: 300 kbps	Intel End-to-End delay < 0.3 sec	Intel E-to-E delay < 0.1 sec	Ops E-to-E delay < 0.2 sec
SLS5		Personnel traffic received > 50%	Intel traffic received > 80%	Ops pkt delay variance < 0.3
SLS6			Logs traffic received > 50%	Ops traffic received > 99%
SLS7			Pers. traffic received > 20%	Logs traffic received > 25%
SLS8				Pers. traffic received > 20%

Service Level Agreement with Specifications for each Campaign Phase

Packet Deliver Success

critical mission / config. mission	equal / equal	equal / logs	logs / logs	ops / logs	ops / ops	intel / ops	intel / intel	
operations flowrate (kbps)	300 / 1	300 / 3	500 / 3	1400 / 3	1400 / 1	1400 / 1	1400 / 2	configured priority operations
intelligence flowrate (kbps)	300 / 1	300 / 2	50 / 2	50 / 2	50 / 2	500 / 2	500 / 1	configured priority intelligence
logisitics flowrate (kbps)	300 / 1	300 / 1	1600 / 1	800 / 1	800 / 3	800 / 3	800 / 3	configured priority logistics
personnel flowrate (kbps)	300 / 1	300 / 4	50 / 4	50 / 4	50 / 4	50 / 4	50 / 4	configured priority personnel

Rates and Priorities of Mission Areas for each Campaign Phase

critical mission / config. mission	equal / equal	equal / logs	logs / logs	ops / logs	ops / ops	intel / ops	intel / intel
total mission flow (kbps)	1200	1200	2200	2300	2300	2750	2750
total prioritized flows (kbps)	1712	1712	2712	2812	2812	3262	3262
all traffic (kbps)	2512	2512	3512	3612	3612	4062	4062
% link exceeded by pri.	-14%	-14%	36%	41%	41%	63%	63%
% link exceeded by all	26%	26%	76%	81%	81%	103%	103%

Command links active: Rates of prioritized and non-prioritized traffic with link usage

phase	equal-equal	equal-logs	logs-logs	ops-logs	ops-ops	intel-ops	intel-intel
ops	100%	100%	0%	42%	100%	100%	60%
intel	100%	100%	4%	100%	95%	15%	100%
logs	100%	100%	92%	100%	5%	0%	0%
personnel	100%	99%	0%	0%	0%	0%	0%

Command links active: Mission area packet delivery success rate

Network Performance Value and Delivery Rate

$$V_c = \sum_{m=1}^{M \text{ mission areas}} C\omega^{\alpha_m} N_m$$

V_c – delivered value for campaign-phase c

C – normalizing constant

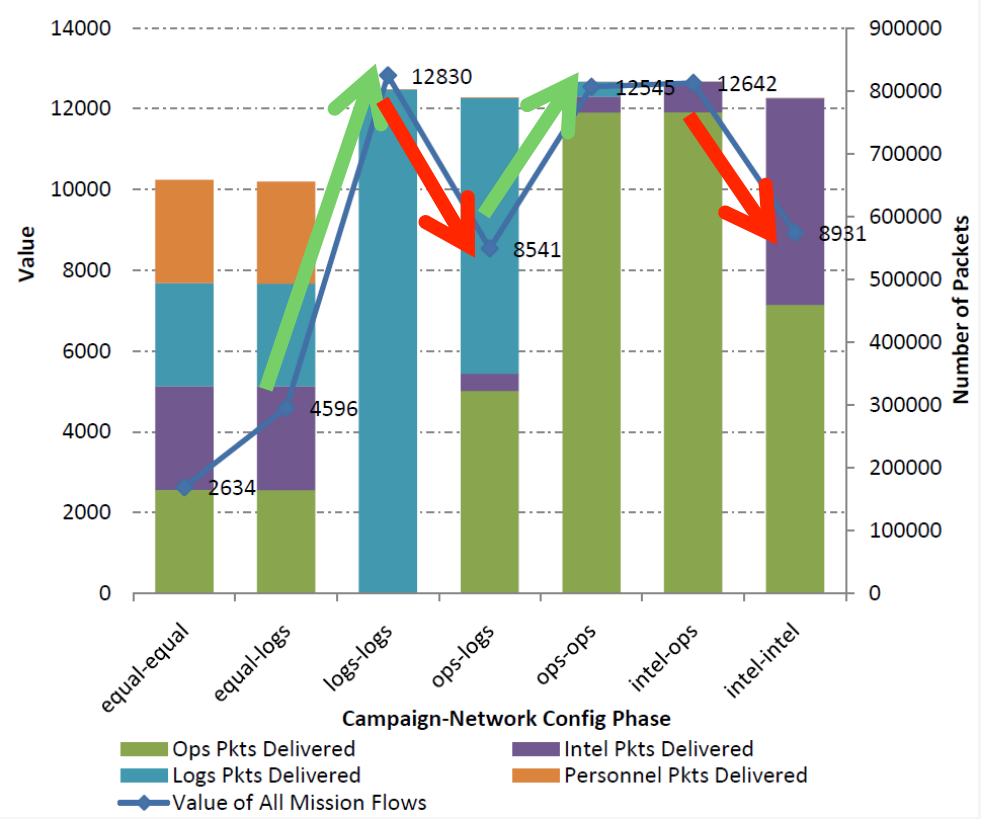
$\omega^{\alpha}{}_m$ – weighted priority level

α_m – priority of mission area m

N_m – numb. packets delivered for mission area m

Value increases as configuration permits primary mission area packet delivery

Value decreases as
- config. mismatches mission
- non-primary mission area delivery falls



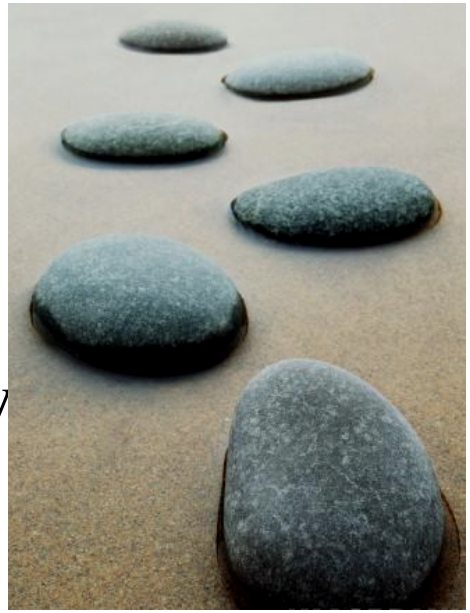
phase	equal-equal	equal-logs	logs-logs	ops-logs	ops-ops	intel-ops	intel-intel
ops	100%	100%	0%	42%	100%	100%	60%
intel	100%	100%	4%	100%	95%	15%	100%
logs	100%	100%	92%	100%	5%	0%	0%
personnel	100%	99%	0%	0%	0%	0%	0%

Command links active:
Mission area packet delivery success rate

OVERALL MISSION FAILURE

Next Steps

- Expand to tailored QoS methods
- Develop more accurate value measure
- Further align mission and threads to policy and QoS protocol tools



- Demonstrate methodology in military use case
  - DoD CIO NII Joint Mission Threads
  - AFRL Information Dir. Airborne Network Platform
- Measure network performance improvements

Summary

- The Quality of Service (QoS) framework has promise to aid in design and operation of the System of Systems (SoS) network which must allocate scarce resources.

- Aligning QoS configuration to mission profiles and priorities tunes network to performance and benefits the overall mission

- QoS alignment
  - alignment to mission yields improved network performance
  - all mission areas need basic/threshold service

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Teamwork is the ability to work together toward a common vision. The ability to direct individual accomplishments toward organizational objectives.

- Andrew Carnegie