Managing Complexity
An Approach to Net-centric Ops

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Sep 2005
Net-centric Operations

Incredible Complexity:
EVERYTHING connected to EVERYTHING

Network Importance:
And it’s a BIG network

This is not your father’s system(s)…
So we shouldn’t be using Dad’s tools
Conventional Network Theory (Based on Erdos)

- 40 years ago, 6 seminal papers that spawned graph theory
- Influencing us to this day
- Key assumptions:
  - Static
  - Passive
  - Random

Erdos: Father of ‘network theory’
Conventional Network Wisdom
(Degrees of Separation)
The Network Isn’t Random!

FDR 22K names
Telemarketing call volumes
Rod Steiger probability (10E-120)

Web Pages: random probability 5 incoming links is $10^{-99}$
But a few pages have a MILLION!
Old vs New

Network Theory

• 1982 Kenneth Wilson wins Nobel Prize (scale invariance predicts power laws)
• Leads to new network assumptions:
  – Static becomes Dynamic (growing)
  – Random becomes Scale Free (power laws)
  – Passive becomes Competitive (fitness rule)

Enterprise complexity requires a different type of System Engineering
Power Laws Predict Hubs/Loose Couplers

It’s Capitalism All Over
- Early Bird Has the Advantage
- The Rich Get Richer
- Fitness Counts

Applies to All Large Networks
- Web pages, Internet, Blogs
- Referenced papers, Actors
- Worm nervous systems, diseases, jobs
Loose Couplers In Large Networks

Takeaway Concepts
Groups + Loose Couplers → Large Networks

What WON’T Work
Making One Big Group
Making Everything Uniformly Connected
Treating Large Networks like Bigger Small Networks
3 Network Value Models

Reed’s \((2^N \text{ Exponential})\)

Metcalf’s \((N^2 \text{ Squared})\)

Sarnoff’s \((N \text{ Linear})\)
Does This New Network View Really Matter?

• We need to view the C2 Enterprise network as:
  – Growing (Plan for incremental spirals)
  – Power Laws (80/20 rule shows where to put energy)
  – Fitness Rule (Let the market have a say)

• Can be applied to
  – Architectures
  – Network Availability Analyses
  – Data Strategies

If we believed this, we would change the way we are building the GIG
A Case Study
Applying Loose Couplers to
Data Interoperability
A Look At DOD Standards

5 JVMF (non-compatible) versions & growing

TADILJ  Link-22  Nato-Ex  JVMF  USMTF  EPLRS  ACARS  ...

R3  R4  R5

K0.1  K5.19  K10.2

18,014,398,509,482,000 variations

Each version has about 100 different messages (e.g., TIDP-R4 has 122)

54 conditional “branch” fields

Impossible to fully implement/test
We want ALL of our systems to speak ALL the standards even though:
Large in Number, Large in Complexity, Versions Change Rapidly,
and No Synchronization of Rollouts!
What’s a System to Do? Pick Subsets (but they’re never the same!)
Same Subset Problems in the AF Link16 Implementations
Can We Use New Network Theory to Help? (Groups + Loose Couplers)

Loose Couplers: Category, Name, Address, Phone Number

Doctors
Lawyers
Plumbers
Realtors

What are the Loose Couplers for Military Data Standards?

TADILJ Link-22 Nato-Ex JVMF USMTF EPLRS ACARS
A Different Approach

• Accept existence of multiple COI standards
• Connect COIs with loose couplers
• 1 Common Language (XML is de facto standard)
• Small Vocabulary (ID key items via Power Law)
  – Take intersection not union of all systems’ data needs
  – Look at frequency usage for what is really valued
  – Conduct due diligence analysis/modeling engineering

“Good Enough” Loose Couplers complement (not compete with) traditional “Best” big standards
Take the Intersection not the Union
Cursor on Target: What, Where, When

Direct Fire Mission:
What: Hostile
Where: 72.558°...
When: 1950Z—...
Details: www.biggun.army/...

Blue Force Tracking:
What: Friendly
Where: 72.31234°...
When: 1930Z—...
Details: www.4thBgd/...

Surveillance results:
What: ISR data
Where: 73°—74°...
When: 1930Z—...
Details: www.intel.af/...

Air Space Deconfliction:
What: Reservation
Where: 72°, 73°, 74°,
When: 1950Z—...
Details: www.batttery.army...
Look at What’s Used, not Spec’d TADIL J-Series Message Frequency

- L16 Net Participant & ID (19% is J2)
- Surveillance Track & Points (66% is J3)
- WHAT WHERE WHEN (J2, J3)

- TRACK MGT (J7)
- MISSION ASSGN (J12)
- PLATFORM STATUS (J13)

- 85%
- 10%
- 2%
- 2%
- 1%

Source: Recorded Traffic, Joint Combat ID Evaluation, 2003 & 2004
Power Law in Data Standards

- The more systems that must adopt a common standard, the simpler it must be.
Is This “Too Simplistic”?  

• Complexity management is not new  
• Abstraction of key details is a proven approach in:  
  – Layered Architectures  
  – Object Oriented  
  – Evolution of Integrated Circuits  
• Disruptive Technologies  

Tradeoff ‘Best’ for ‘Good Enough’ to shift from ‘Local’ use to ‘Enterprise’ use and shift from ‘Long’ developments to ‘Rapid’ developments!
Validating Theory with Experimentation

10 Lessons Learned Using Cursor on Target as A Loose Coupler
Operation Northern Watch
(Intel to F15E)

1. No change to existing code so very low cost
2. Programs synchronize strategy not schedule
Deployed BAO Kit Improved Targeting Accuracy & Reduced Timeline By 70%

Old Manual Method: 27 Minutes

M2M with CoT Method: <8 Minutes

“Cursor on Target... was right on target ...magnificent”
Gen John Jumper
CSAF
AC130 Gunship Situational Awareness
(LINK16 SA Picture-AC130)

4. Data is agnostic to radio transport (e.g., Link16 radios aren’t needed to see Link16 data!)

5. Rapid design (typically weeks)
AC-130 Gunships Using CoT to Get Link16 Picture over ARC231 Radios

“no one had a solution... in 10 days it [CoT] was working in our labs”
Mike Stephens
AC-130 Program Office
6. Really can support pub/sub service; profiling, dynamic rules, access rules, prioritization, etc.

7. N-squared (really $2^N$) net-centric data flows connect COIs together
JSTARS ICAN Funded to Send Key Data Using IP Over Today’s Radios

IP Based System
- E-mail
- Imagery
- SA
- Chat
- IP Transport
- Radio Driver

PC + Legacy Radio

Dr. Lin Wells (OSD/NII) supports our “IP over Legacy Radios” efforts
Joint Operational Testbed System (JOTBS)
(JFCOM UAV Forward Look ACTD)

- Joint Operational Testbed System (JOTBS)
- JFCOM UAV Forward Look ACTD

**8. Scalable:**
- AF, Army, Navy, Marines, Spec Ops, Intel Coalition, UAVs, Munitions, Chat, etc.
Deployed UAVs
Using Cursor on Target for SA

“we are using the C2PC COT adapter for our Scan Eagle UAV’s. ..working extremely well…we want more!”

S/F, Maj Rob Buzby
IMEF Info Management Officer
Camp Fallujah Iraq (11/12/04)

UAV SA JFCOM Cmdr. James M. Joyner, called the cursor-on-target scheme “a de facto standard for tactical system integration." (1/06/05)

DEPSECDEF initiative recommending CoT for sharing UAV SA
9. Mission boundaries are merging: TCT, BF, ISR will become integrated;
Critical to experiment with user (warfighter) frequently
CURSOR ON TARGET (COT) WORKED WELL AS AN INTEGRATION TOOL AND WARRANTS FURTHER ANALYSIS AS AN ENTERPRISE DATA STRATEGY.

--Navy Assessment of CoT from JEFX experiment
CAF-MAF Global ConOps Synchronization
(Tankers on Target)

10. Netcentric strategy outruns & dramatically expands CONOPS
B-1 Reaction to CoT Sent over Combat Track II Radios

“I flew with it and it was amazing…a huge leap in combat …this system works now and we flew it last night without any additional cost or hardware”

GEORGE A. HOLLAND III, Maj. USAF
Asst Ops Officer
77th WPS, USAF Weapons School
Traditional Systems Engineering is Different than Enterprise Engineering

The Watchmaker: Everything has its place.

The Gardener: Plant, Fertilize, Weed; Repeat.

“Good Enough” may be “Best” for the Enterprise, and what’s “Best” for 1 may not be “Good Enough” for the Enterprise