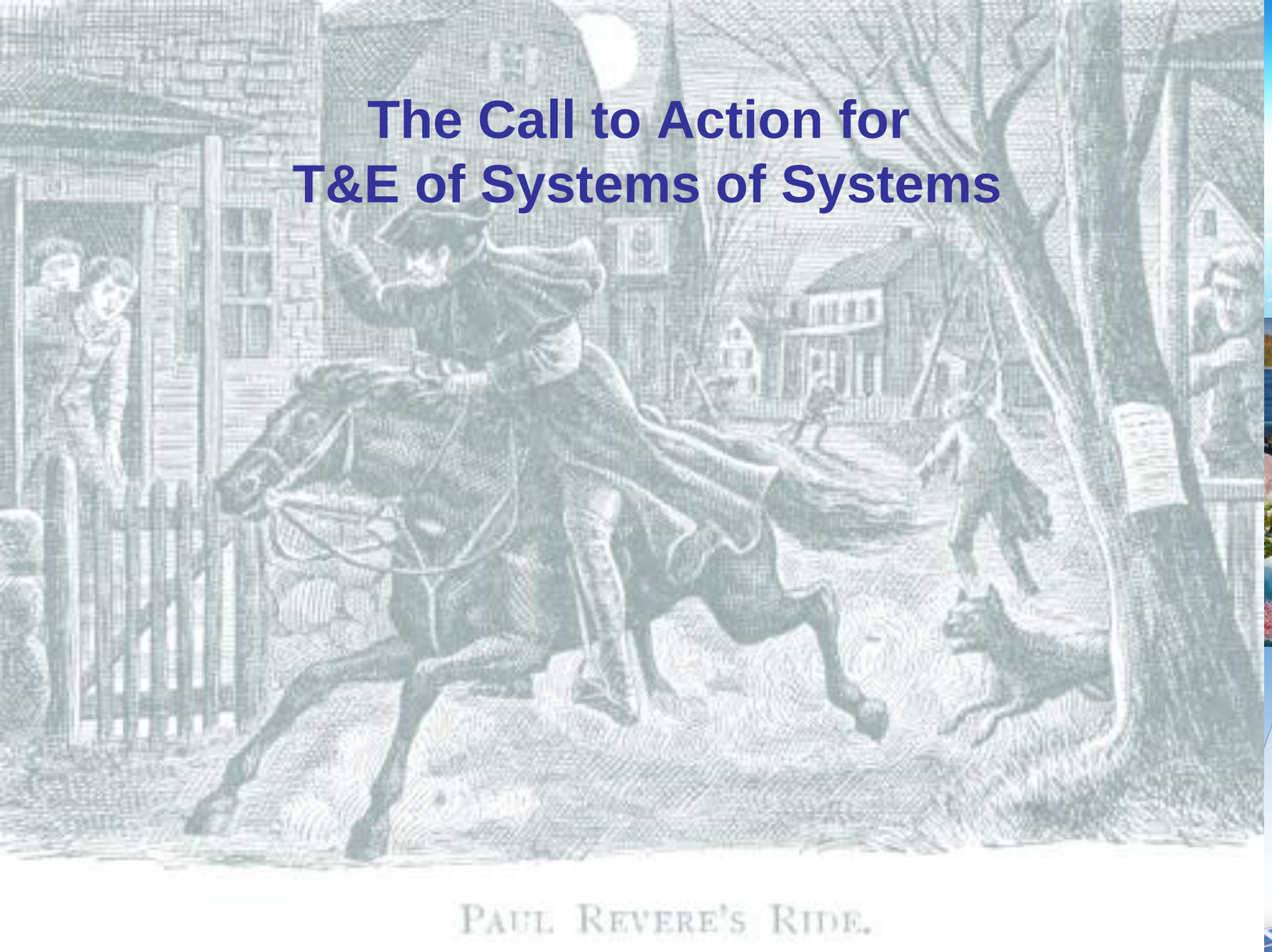
# The Call to Action for T&E of Systems of Systems





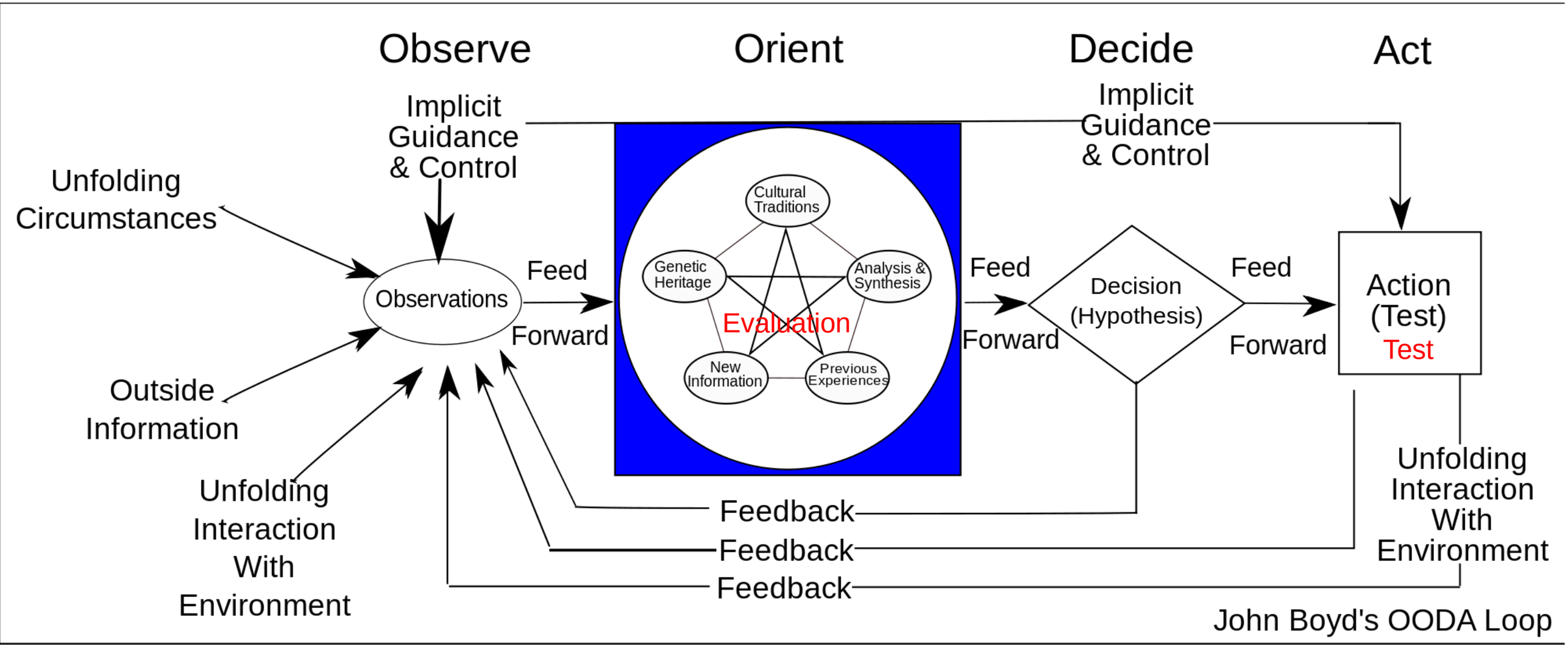
## (manned – unmanned – autonomous – networked – self-evolving)

Presented by Thomas Tenorio, Senior Principal Systems Analyst,
WSMR/ATAMIR/NCI Test Engineering & Analysis Support

Presented to Enchantment INCOSE Chapter on March 14, 2012

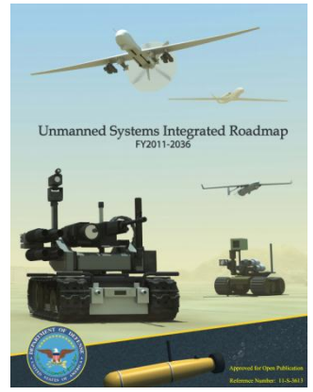
**Meeting Abstract:**

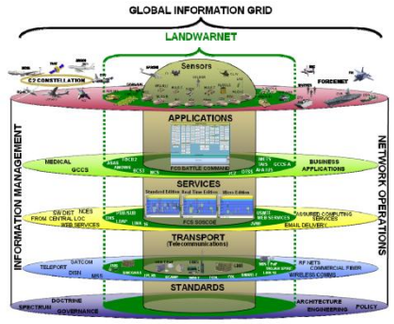
To outline the System Engineering (SE) challenges that arise when devising independent and objective Test and Evaluation (T&E) for Warfighter systems that are increasingly intelligent, unmanned, interconnected, and self-organizing, particularly at brigade scale and composed of hundreds of heterogeneous components, also called System of Systems.

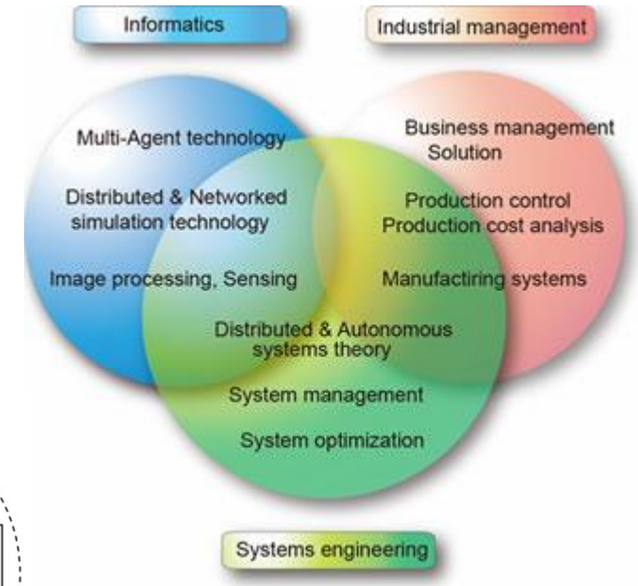


Presenter Info: Thomas Tenorio

Systems Engineer & Senior Principal Systems Analyst with 28 years in Test and Evaluation of Complex Adaptive Systems (Networks, Controls, Unmanned and Autonomous Systems Test, Targets, Directed Energy, Computer Science, Information Technology).

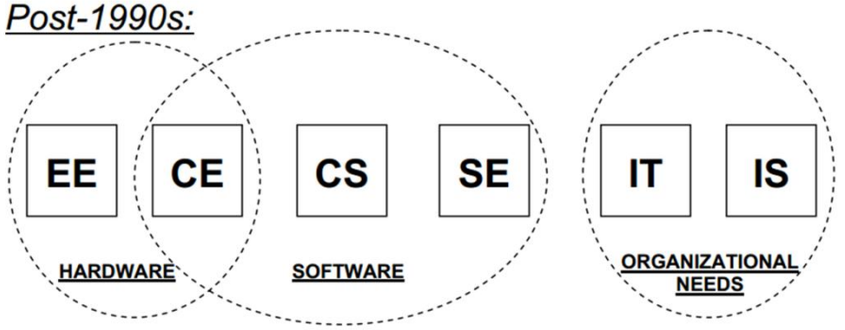


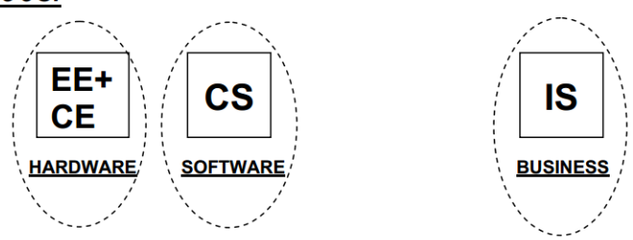


*Post-1990s:*

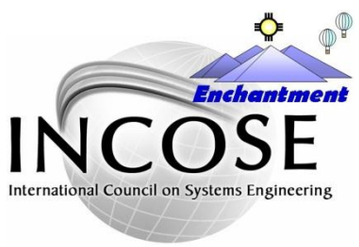




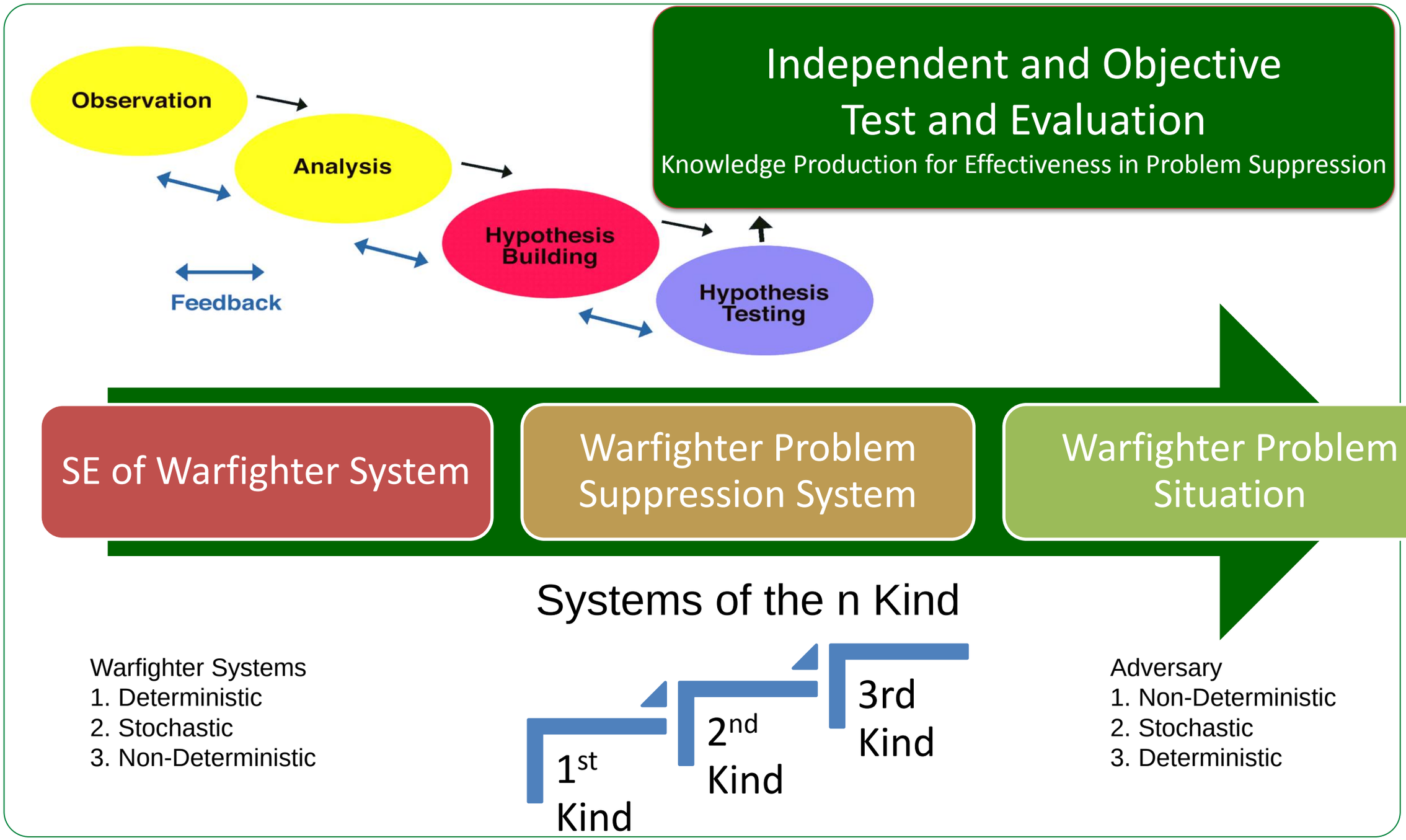
*Pre-1990s:*







The SE challenges that arise when devising independent and objective test and evaluation for Warfighter systems that are increasingly intelligent, unmanned, interconnected, and self-organizing, particularly at brigade scale and composed of hundreds of heterogeneous components, also called System of Systems.



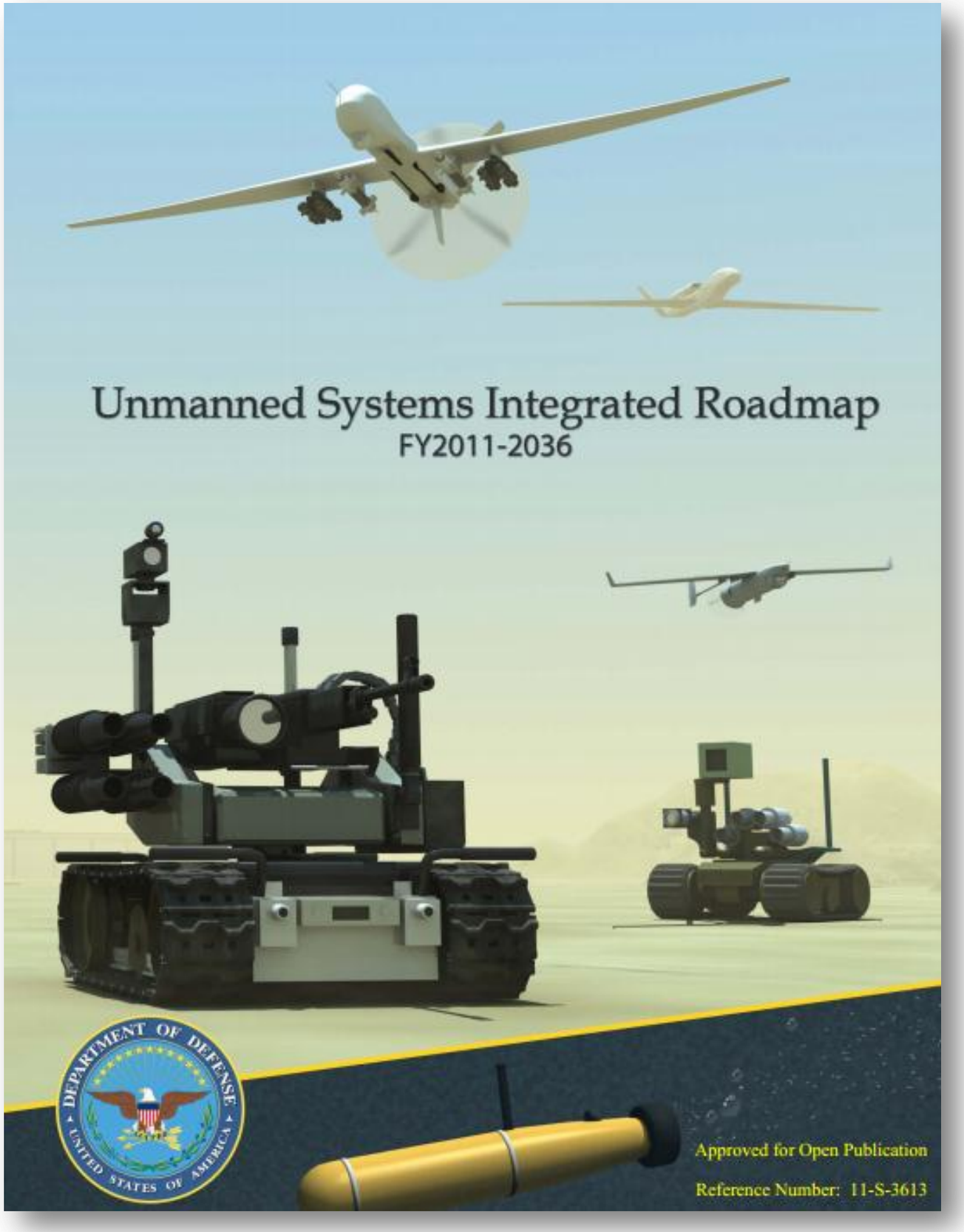
**CONTEXT 1:** The DoD Unmanned Systems Roadmap FY2011-2036

Establishing an 11% footprint for T&E

Establishes Operational Mission Profile for T&E of Unmanned Systems

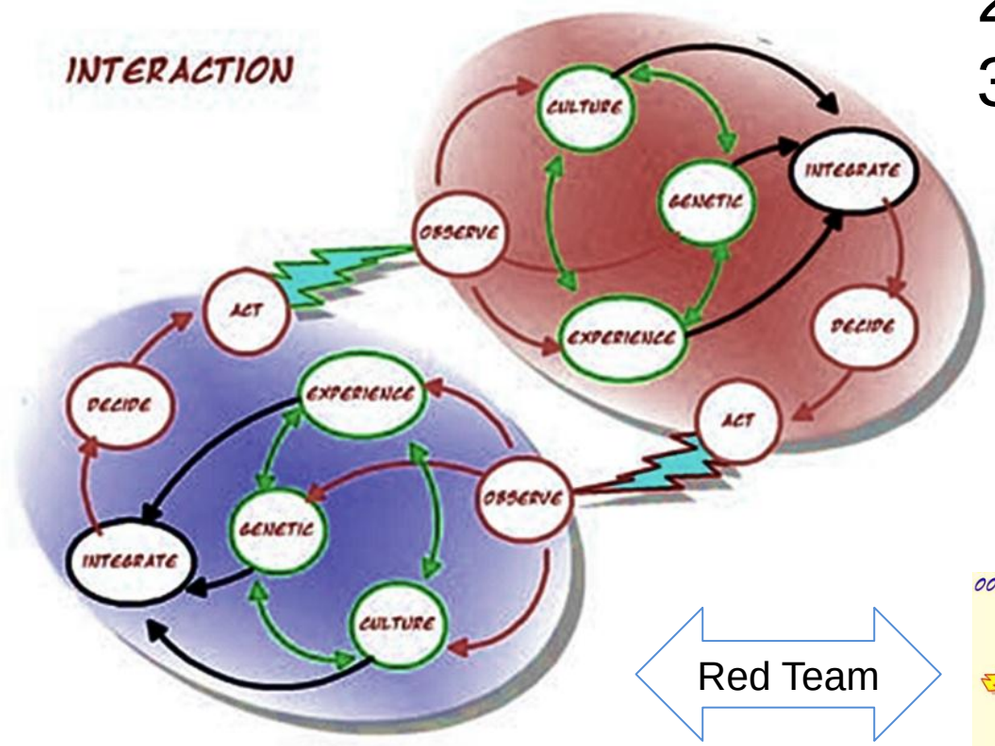
A $36B endeavor of the Department of Defense

A ubiquitous and persistent trend towards of computer and networks advantage



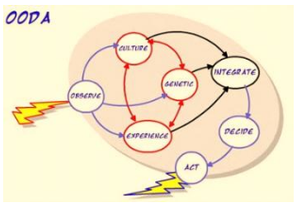
**CONTEXT 2:** Direct involvement of Warfighters who clarify the spectrum of trustworthy knowledge they must have for deciding suitable, effective, safe, secure and survivable SOS's in the field.

Red Force Disruption
1.Non-Deterministic
2.Stochastic
3.Deterministic




Blue Force Intent
1.Deterministic
2.Stochastic
3.Non-Deterministic

Red Team

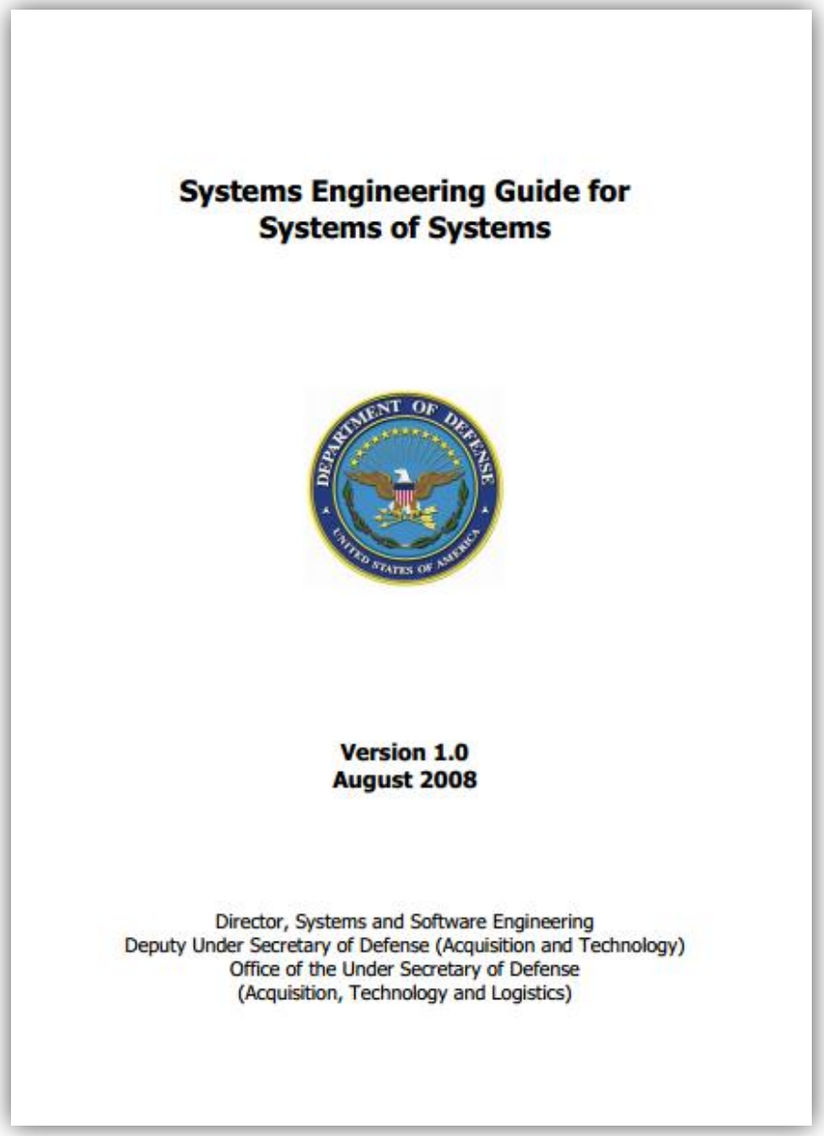



Red Team Emulation
1. Non-Deterministic
2. Stochastic
3. Deterministic

http://isobe.typepad.com/sketchpad/2004/04/more_thoughts_o.html

# Blue Force versus Red Force
# Problem Suppression versus Problem Situation

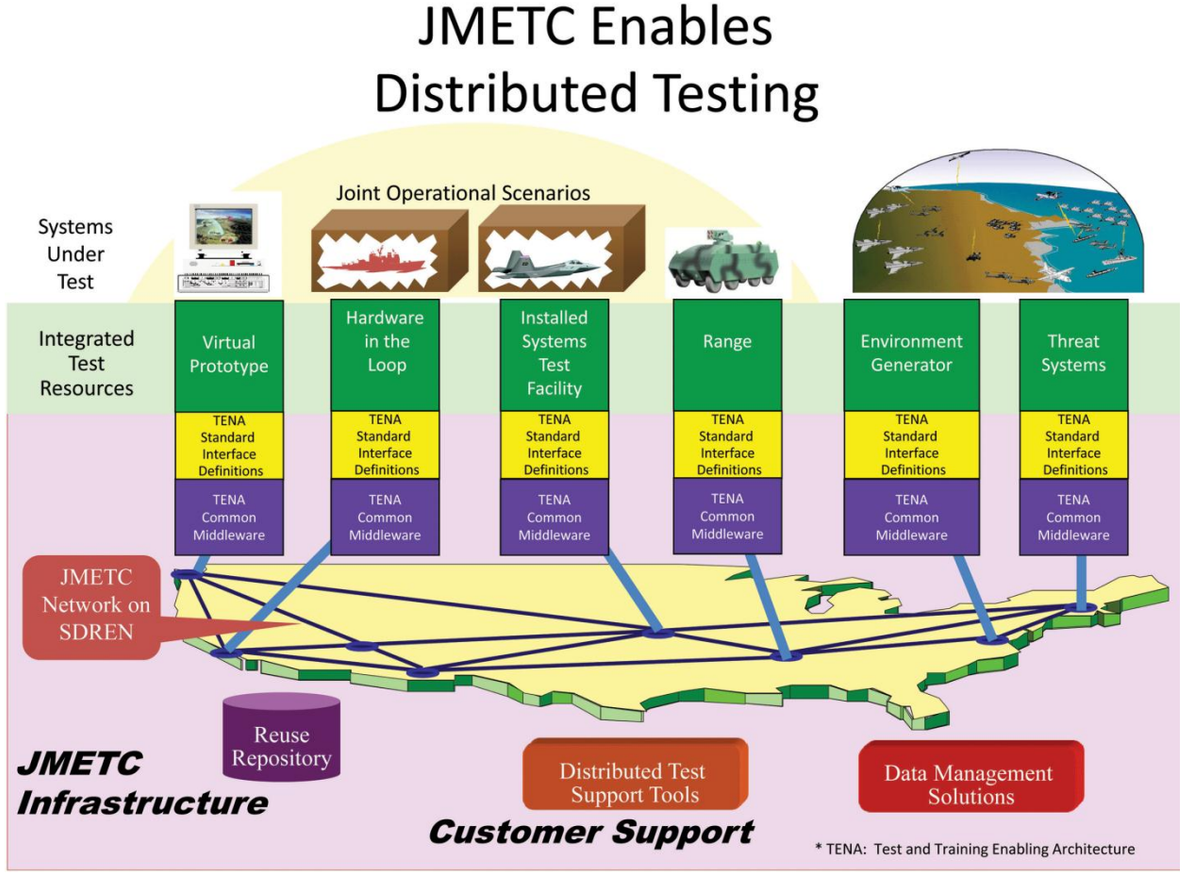
**CONTEXT 3:** The effectiveness of today's "DOD Guide for SE of SOS" and of the Joint Mission Environment Test Capability (JMETC) designs of the SOS configurations to be tested.



**Systems Engineering Guide for Systems of Systems**

**Version 1.0**
**August 2008**

Director, Systems and Software Engineering
Deputy Under Secretary of Defense (Acquisition and Technology)
Office of the Under Secretary of Defense
(Acquisition, Technology and Logistics)



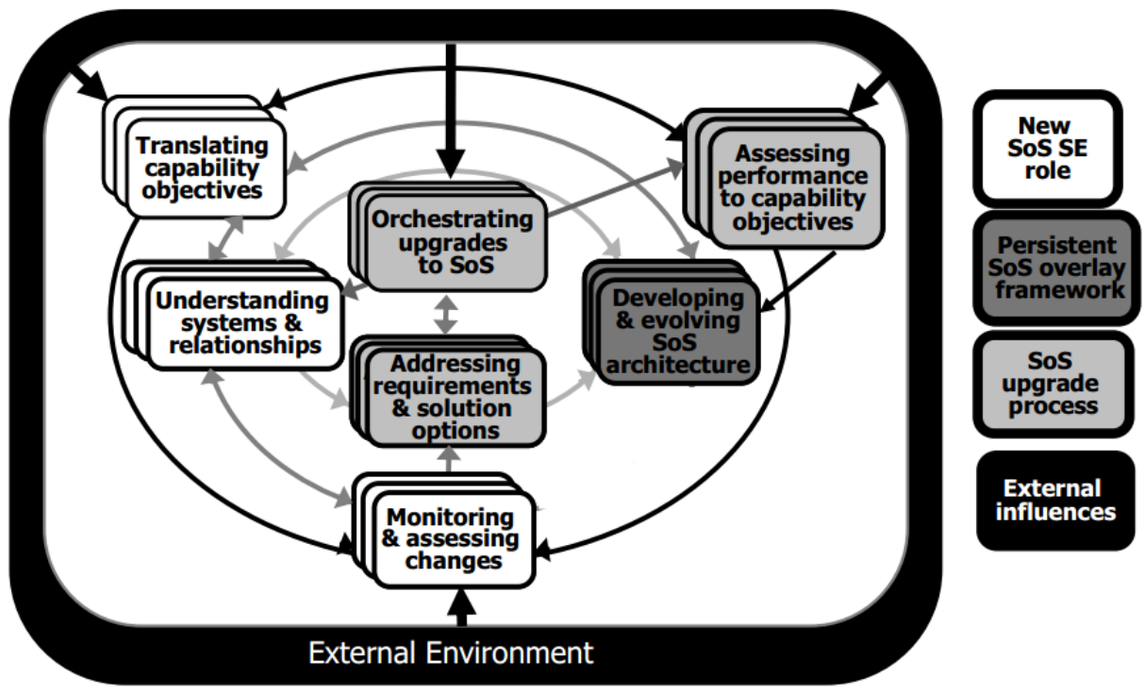
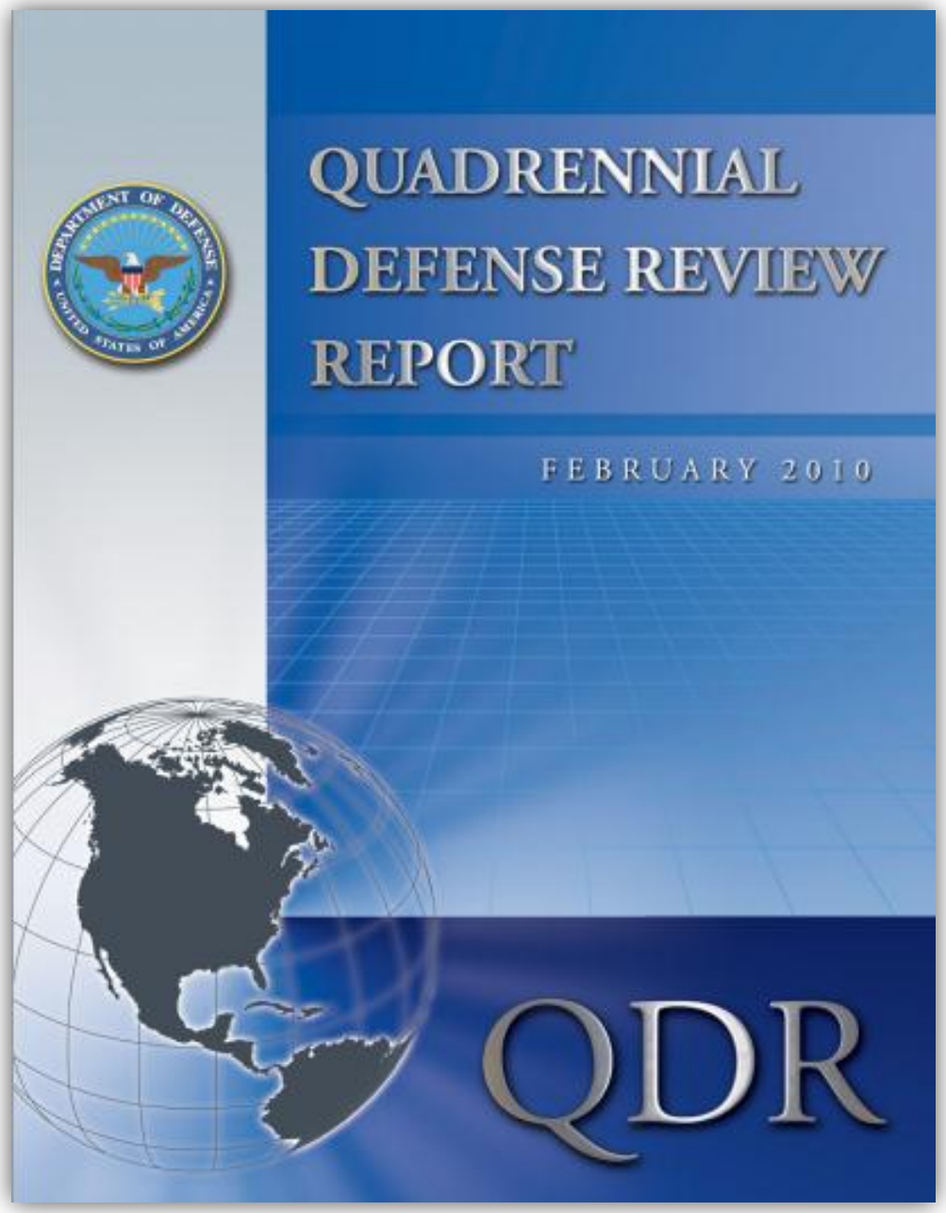




**Figure 4-1. Core SoS SE Elements and Their Relationships**

**CONTEXT 4:** The warfighter engagement scenarios that anticipate the realities of asymmetric and other kinds of warfare.




Institutionalizing Rapid Acquisition Capability

America's current and future adversaries will make innovative use of readily available emerging and commercial technologies and employ **asymmetric tactics** to disrupt the superiority of U.S. military power. The QDR outlines a number of enhancements to rebalance the force consistent with defense priorities and to better prepare our forces for the challenges ahead. The Department must not only prepare for those threats we can anticipate, but also build the agile, adaptive and innovative structures capable of quickly identifying **emerging gaps** and adjusting program and **budgetary priorities** to **rapidly field capabilities** that will mitigate those gaps.

Summary of the the panels and papers, and report on the objectives, impediments, initiatives and resources that were identified in the Town Hall and World Café sessions held at the January El Paso ITEA conference and led by John Thomas, President, INCOSE.

## 2012 The T&E of System-of-Systems Conference

January 24 - 27, 2012
El Paso, Texas
*Hosted by the ITEA White Sands Chapter*


### Program Description

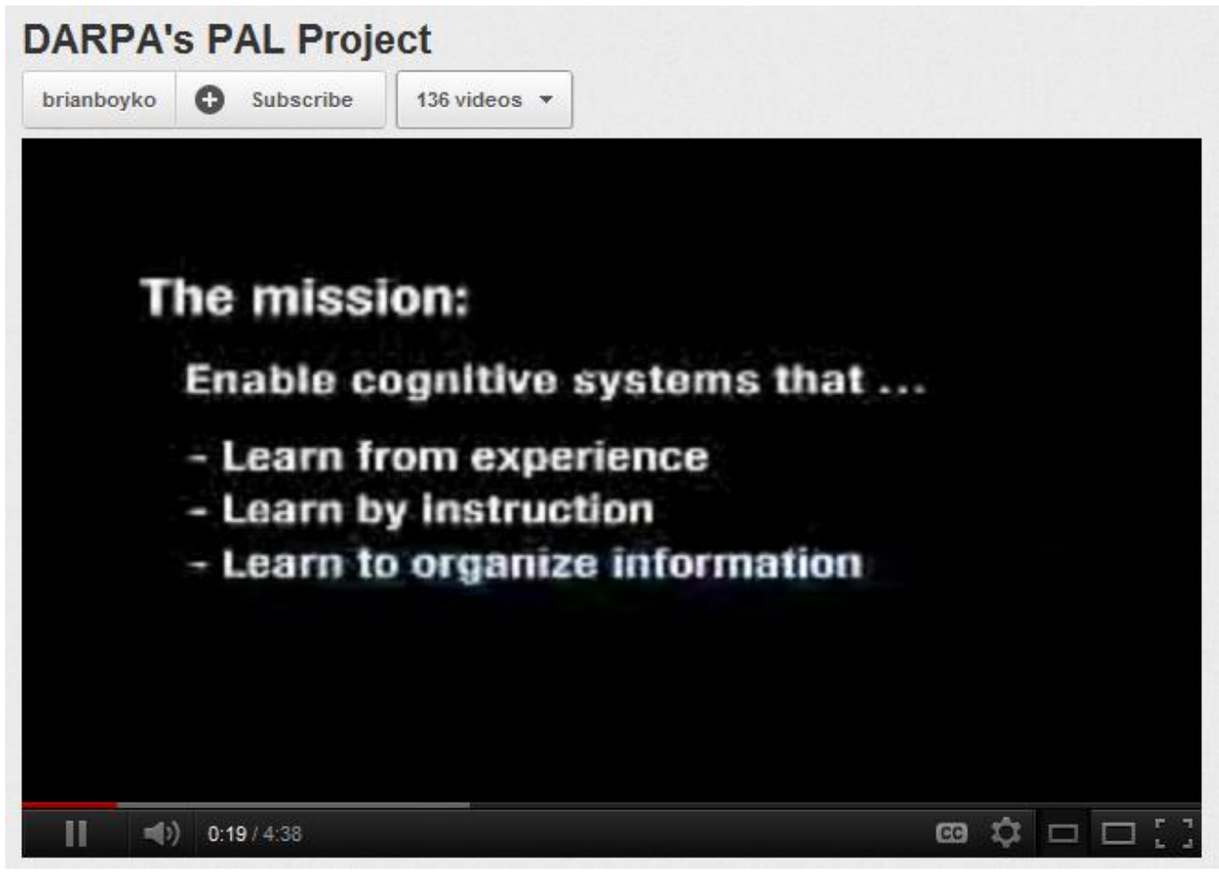
The new topic, 'The T&E of System-of-Systems,' has drawn an enormous amount of interest, and we invite all 'Systems' type T&E Engineers and Operators to join us as we dive into over 40 presentations covering a myriad of T&E in System-of-Systems' topics. Speakers, panelists, authors, and leaders from the Department of Defense, Homeland Security, Federal Aviation Administration, Academia, and Industry will come together with their ideas and tools, organizing one of the most robust conferences we have ever planned.

# The views of one industrial participant from iRobot Corp.

The program manager for this project under DARPA is Dr. Robert Kohout, formerly a research scientist at Strategic Analysis part of General Dynamics, which is now Intelligent Automation, Inc.  If we go to Dr. Kohout's former employer, we can look at a PAL system called ARTeMUS which acts very much like a moving, learning network to assist combat troops in urban environments.

The Personalized Assistant that Learns (PAL) program is developing machine learning technologies to make information understanding and decision-making more effective and efficient for military users. The program is creating robust software assistants that can help users perform a wide variety of tasks while adapting to the environment and the user's goals without programming assistance or technical intervention. PAL technologies will reduce the need for large command staffs, thereby enabling smaller, more mobile, less vulnerable command centers.

**The iPhone 4S' Talking Assistant [SIRI] Is a Military Veteran**




http://www.youtube.com/watch?feature=player_embedded&v=BF-KNFlOocQ

Workshop 1

PAUL REVERE'S RIDE.

# Simulation-Based Engineering of Context Sensitive Systems

Dr. John R. Clymer, INCOSE Fellow

**Module 1:**

**Simulation-Based Systems Engineering, System of Systems (SOS), Context-Sensitive Systems (CSS) Simulation, Operational Test & Evaluation of CSS**

THE T&E OF SYSTEM-OF-SYSTEMS CONFERENCE

January 24 - 27, 2012
El Paso, Texas

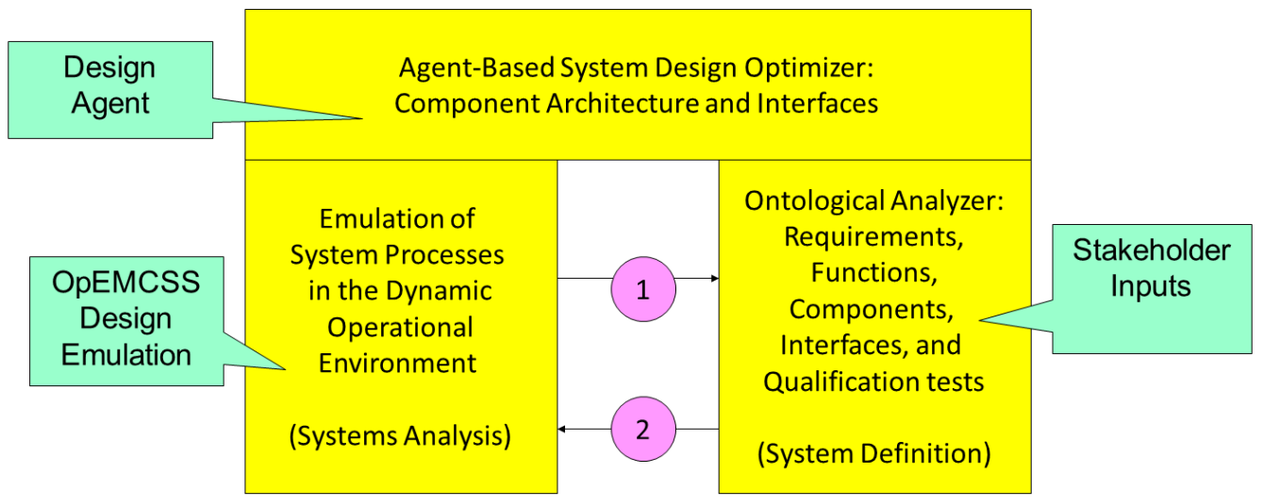


# SBSE FRONT END PROBLEM

- Requirements are generated that:
  - do not contribute to the problem solution or are counterproductive to achieving the optimal performance, cost, and schedule.
- Systems engineering projects fail when the stakeholders say "That's not what we asked for?"
- Simulate alternative solution concepts:
  - driven by the dynamic demands of the operational environment
  - Requirements obtained are: the number of resources, reaction time budgets, estimates on interface capacity, RMA requirements, and system management rules.



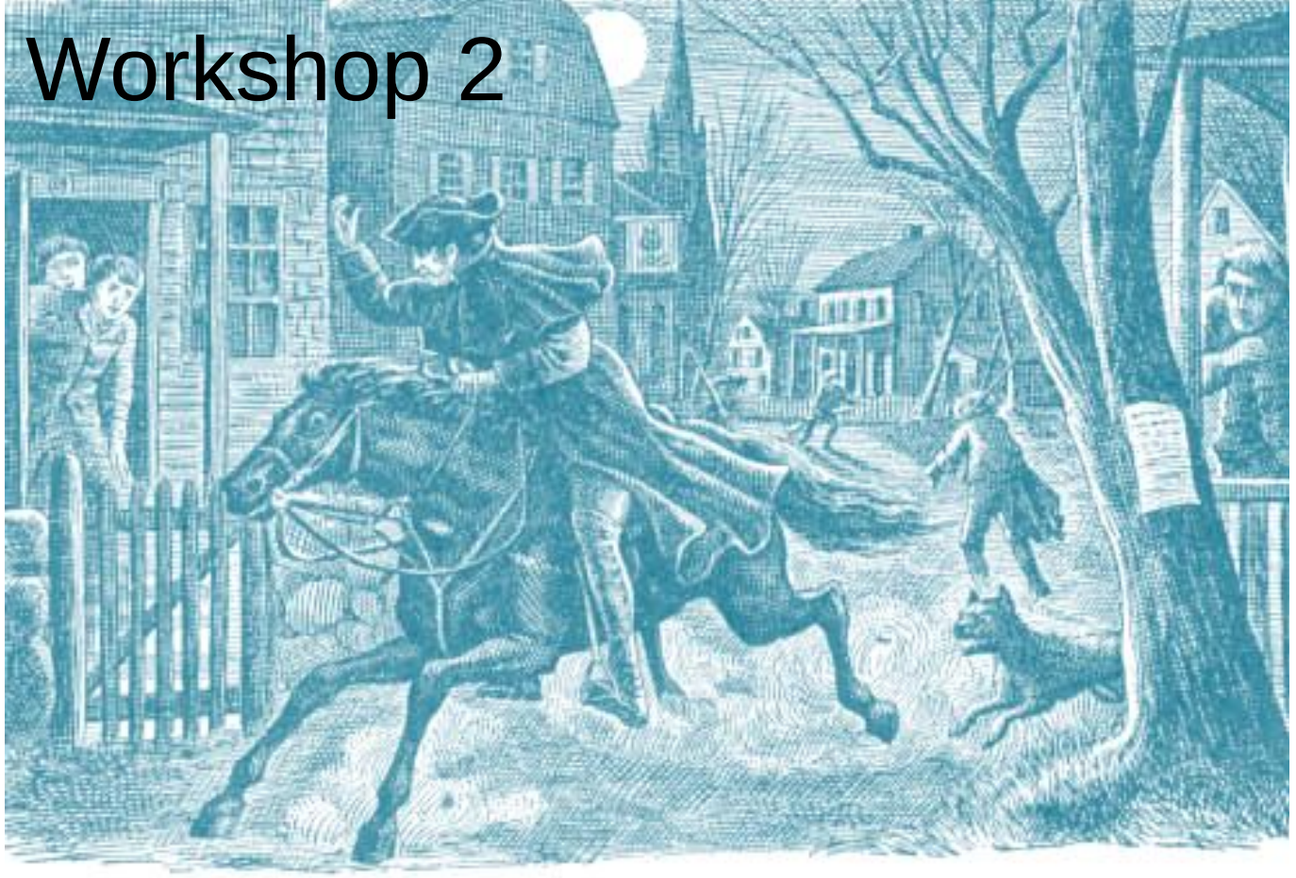
# Simulation-Based Systems Engineering




1 This interface allows input to ontological analysis of system operation and performance information.

2 This interface provides KPP and other requirements to dynamic model to test requirement consistency with required system performance and cost.

Workshop 2



PAUL REVERE'S RIDE.

# SE → T&E → $\Sigma_n$(SOS)

## A Tutorial

ITEA Conference, Jan. 2012, El Paso, TX

By
Jack Ring, Educe LLC.;
Thomas Tenorio, NCI Information Systems;
Phil Djang, Ph.D., Army Research Lab;
Filiberto Macias, Systems Engineering Directorate, WSMR

## Agenda

- Introductions: Ring (1300-1325)
- The Field of Discourse: Ring (1325-1355)

- SOS Viewpoint: Tenorio (1355-1425)
- REFRESHMENTS (1430-1445)
- Mission Viewpoint: Djang (1440-1510)

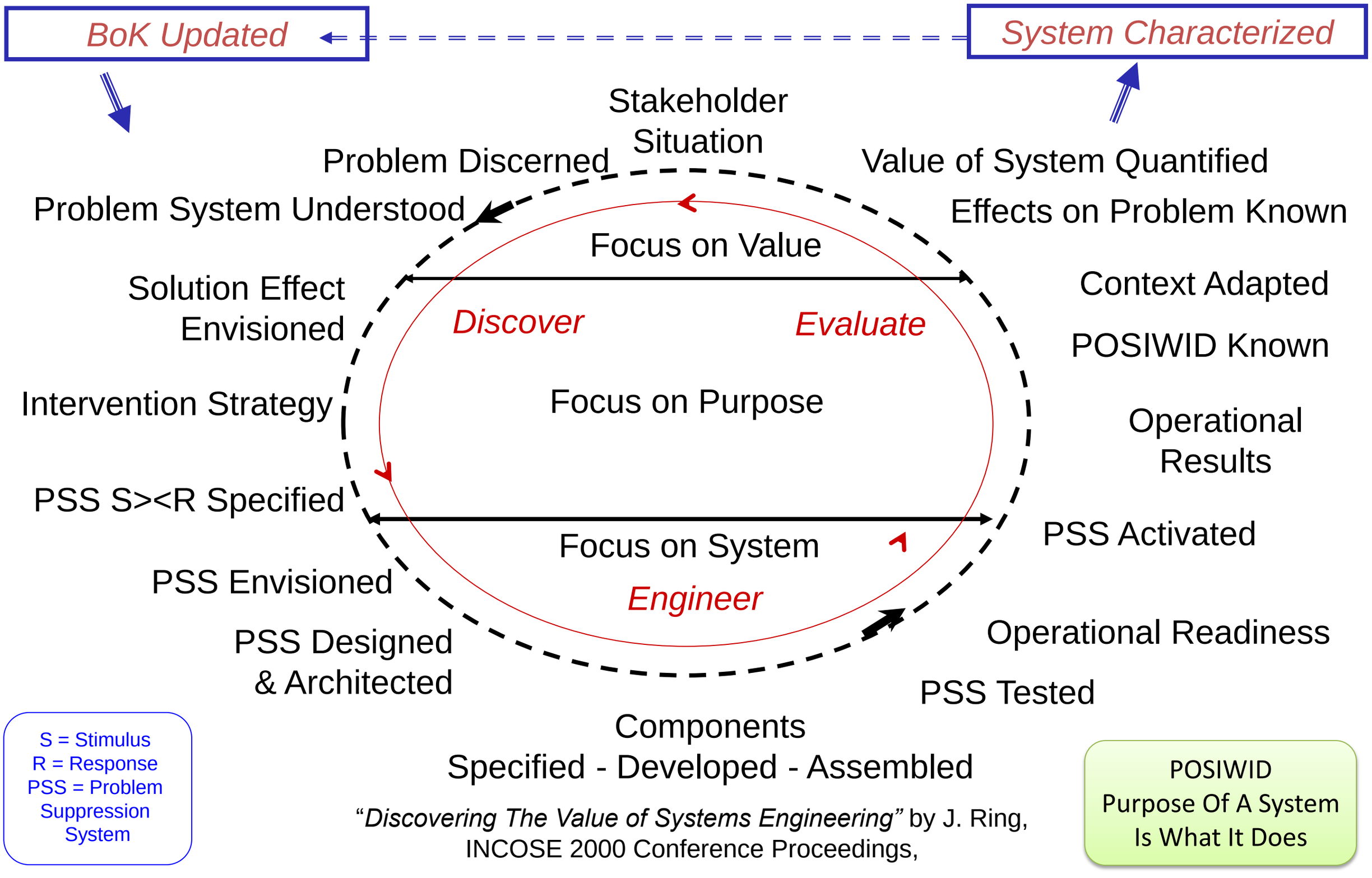
- T&E Viewpoint: Macias (1520-1550)
- SE of T&E of SOS Viewpoint: Ring (1550 – 1620)

- Wrap Up: Tenorio (1635 – 1700)

## The Promise

- encourage community transition to a viable paradigm for assessing SOS readiness
- introduce a capability-pull mode of creating effective SOS's
- foster participant understanding of
  - model-based SE
  - a unified readiness assessment system equal to the extent, variety and ambiguity of the problem system
  - modeling SOS configurations and user engagement scenarios
- work first examples of achieving more with less, specifically a 10X faster and less expensive capability through an enterprise that produces platform-based, composable family of systems, whenever, wherever.

# SE of T&E General Scenario



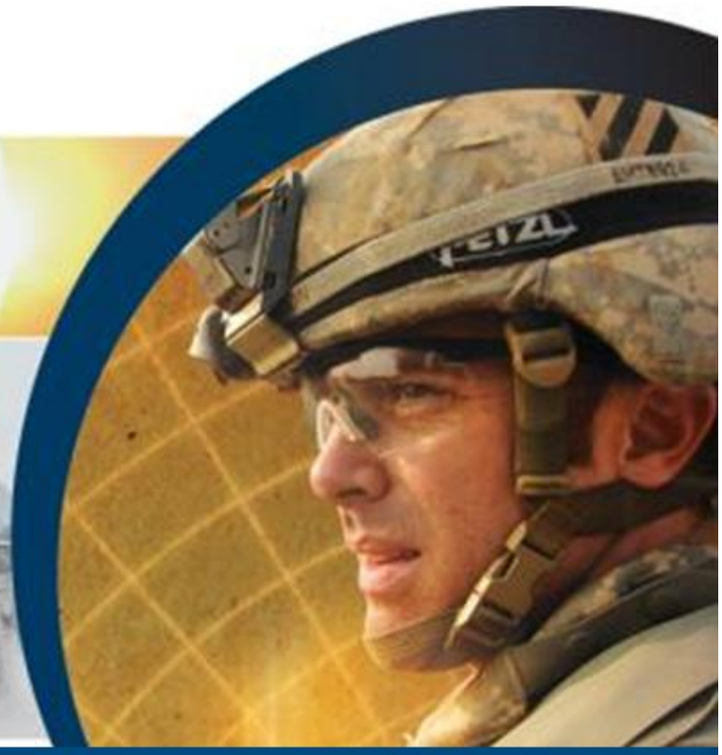

S = Stimulus
R = Response
PSS = Problem Suppression System

"*Discovering The Value of Systems Engineering"* by J. Ring, INCOSE 2000 Conference Proceedings,

POSIWID
Purpose Of A System
Is What It Does

Army Test and Evaluation Command

ATEC



# Test and Evaluation of System-of-Systems

**MG Genaro Dellarocco**

January 25, 2012

Army Proven
Battle Ready

# ATEC Mission

Plan, conduct, and report the results of tests, simulations, experiments, and evaluations to decision makers in order to ensure our Army's Warfighters have the right capabilities for success across the entire spectrum of operations.

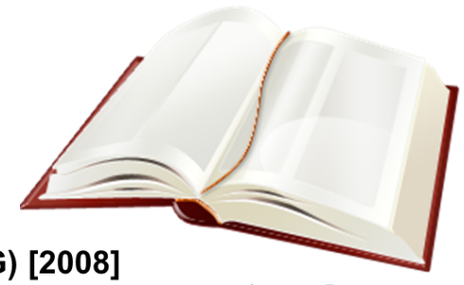
Conduct rapid testing in direct support of the OCO Warfighter in order to provide capabilities and limitations of untested weapon systems issued directly to Soldiers conducting combat operations.





# Definition *

System(s) 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



*** DoD Defense Acquisition Guidebook (DAG) [2008]**





# ATEC & NIE

***Cooperative Effort:***
Brigade Modernization Command
Director System of Systems Integration
Army Test and Evaluation Command

Network Evaluation TRIAD

**Test Lead**

**Analysis Lead**

**Critical Support and Infrastructure**





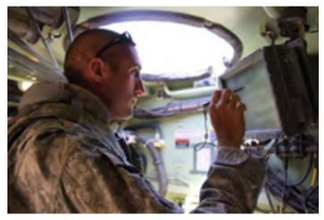
# Network Integration Evaluation (NIE)

**What is the NIE?**

… a series of semi-annual evaluations designed to integrate and mature the Army's tactical network by placing a large number of emerging systems with Soldiers in operational scenarios.

**What will NIE allow us to do? – Demonstrate Interoperability Early**

… develop a single battlefield network able to push information to our Soldiers and link them to command posts, vehicles on-the-move and higher headquarters.



**It's a new way of doing business –**
**a fundamental change in how we deliver capabilities to our Soldiers**

# John A. Thomas

## Sr. VP Booz Allen Hamilton

## President INCOSE

John A. Thomas. a Senior Vice President at Booz Allen Hamilton and its Chief Systems Engineer, specializes in delivery of large-scale systems engineering and integration services. His areas of systems expertise include systems engineering and integration, system analysis, solutions delivery, and conflict management and resolution associated with singular complex problems.

Mr. Thomas is the president-elect of the International Council of Systems Engineering (INCOSE), and will be the organization's president in 2012. He is a prolific writer and speaker on the integration of systems engineering with business analysis and program support services.

Mr. Thomas has worked in commercial and public sectors, predominantly with organizations whose missions are aligned to U.S. defense, intelligence, and homeland security.


John’s keynote video highlighted five aspects of test and evaluation of systems of systems: the system-of-systems (SoS) advantage, SoS mission metrics, single system self-limits in the SoS context, SoS safety envelope, and SoS cyber vulnerabilities. John challenged the systems engineering and test-and-evaluation communities to answer five core questions

# Contextual Questions

## (as addressed by John Thomas in introduction)

1. What can the System of Systems do that none of the standalone systems are able to offer independently?
2. What are the resulting mission-relevant performance metrics of the system of systems? (availability, survivability, and so on)
3. What can't a standalone system be expected to do any longer when operating within the context of the System of Systems?
4. What is the System of Systems' safety envelope? - the performance boundary outside of which it cannot be trusted to protect its users or operators.
5. How vulnerable to cyber activities is the system of systems, and when compromised, what are the resulting dangers?

THOUGHT EXPERIMENT: Consider the challenge of a SIRI augmented System of Systems. Does SIRI a non-deterministic subsystem create problems if the System of System is Deterministic?

# Jack Ring

You don't know Jack

- 1955 – Present.
- System Test & Evaluation (Atlas ICBM Radio Guidance System) → System Engineering (State-determined → Stochastic → Non-deterministic Systems).
- GE 20, Honeywell 10, Edelbrock 3, Ascent Logic 2, IBM OTP 1.
- Kennen Technologies LLC, OntoPilot LLC, Educe LLC.
- More than 50 systems, most including humans as active components. Involved Newbies, Crossovers, Remedial cases, Geniuses and wonderful Mentors.
- 1961: race car telemetry. 2012: SySTEM.
- Tutorials, Papers and Panels; INCOSE, INCOSE IL, ITEA, ICSEng, ISSS, IEEE SMC, IEEE SysCon, NIST.
- Co-chair, INCOSE WG's for
  - Intelligent Enterprises, 2002-2007
  - Motor Sports as learning environment, 2008 –
  - Autonomous Systems T&E, 2009 -

# Intended Outcomes:
# A new T&E paradigm. Enthusiasm to Transition. Justifiable budgets.

PEOs
PMs
Test Range Executives

Joint Operations
Brigade-scale
Warfighters

FAA, FCC, DHS
Allies,
Congress

## Actionable Knowledge

With Warfighters
By Purple-suits
And Civilian SME'S

**WHY**

**WHO**

**WHEN**

SE →
T&E →
SOS

**WHERE**

**HOW**

"Day 2"of SoS Projects
Until End of Life
At pace of SoS evolution

Development
Field Ops
Training Exercises
*in situ (Battlefield)*

Whole system span,
e.g., DOTMLPF
Model-based SE
Non-deterministic SOS's

**WHAT**

Knowledge Discovery/Usage →

Adequate, Accurate, Timely
Trusted, Cyber-Assured
Independent & Objective

Simple → Autonomous
Engagement-specific
Physical & Cyber

← New User Paradigms

More with less

( T&E enterprise, Many Kinds of T&E, Family of T&E systems)

# Dr. Regina M Griego

Principle at Sandia National Laboratories

INCOSE Fellow

Dr. Griego is a respected leader in the areas of requirements engineering and systems engineering. Her academic and industry focus incorporates modeling as a way to formalize problem understanding and develop requirements. Dr. Griego has also been instrumental in enterprise modeling and improvement in various application domains throughout her career. She is a Fellow of the INCOSE.  Dr. Griego was the Technical Director for INCOSE in 2009-2010 and Founding President of the INCOSE Enchantment Chapter.

Dr. Griego has 28 years of experience in various positions including first line technical management, leading technical integration on programs, as a lead systems engineer or requirements engineer, teaching requirements and systems engineering, building requirements/systems engineering capability, and as a design engineer. She has worked at Sandia or NNSA for 14 years of her career in the area of Nuclear Weapons and currently in Nuclear Non-Proliferation.  She has a Doctor of Philosophy in Engineering from the Department of Electrical and Computer Engineering from NMSU, an MS in Computer Science from CU Boulder, an MS in Electrical and Computer Engineering from University of Arizona , and a BS in Electrical Engineering and Computer Engineering from NMSU

# Panel Objectives

- Explore the relationship and synergy between Systems Engineering and T&E in particular in the context of System of Systems
- Create a dialogue among panelist that represent different stakeholders in the T&E of System of Systems
- Begin to identify challenges that the Systems Engineering and T&E community need to address in order to field future System of Systems

## US Army Col. (Ret.) Otis Ferguson

Senior Military/Systems Analyst

RESEARCH ANALYSIS AND MAINTENANCE, INC.;

Col Ferguson is a qualified Senior Program Manager, Senior Test Officer, and Senior Systems Engineer who is both Joint and Army qualified with over 30 years of experience. Otis has spent 10 of the last 12 years in various leadership positions in small businesses supporting the Department of Defense. Otis has a BS in Electrical engineering from New Mexico State University (NMSU), a M.S. Computer Science, (Industrial Engineering Minor); Operations Research, Systems Analyses/Systems Management Degree (ORSA) Certification, US ARMY 1980.



## Bob Kohout

VP for Research

iRobot

Bob Kohout joined iRobot as the Vice President for Research in late 2011. Prior to that he was a Program Manager in DARPA's Information Innovations Office. While a Program Manager at DARPA, he managed several programs, including the Personalized Assistant the Learns (PAL), COORDINATORS, Military Applications of Learning Technology and Architectures (MALTA) and Oh By the Way (OBTW). During his time at DARPA, Dr. Kohout directed a variety of empirical evaluations of complex software systems, including rigorous experimental evaluations designed to measure the technical performance of software, small controlled field studies of effectiveness involving human participants, and large operational assessments involving military units. Prior to becoming a Program Manager, Dr. Kohout supported DARPA as a technical advisor and was involved in various capacities in the evaluation of robotic systems in the LANDroids, Learning Locomotion, and Learning Applied to Ground Robots programs.

THE T&E OF SYSTEM-OF-SYSTEMS CONFERENCE

## Dr. Catherine Warner

Science Advisor

Director, Operational Test and Evaluation

CATHERINE WARNER, PH.D., became the Science Advisor for DOT&E on September 13, 2010. She serves as the technical advisor to the Director on all matters of testing and evaluation in the DoD. Previously, Dr. Warner was an assistant director and head of the Air Warfare group for the Operational Evaluation Division at the Institute for Defense Analyses (IDA). She managed a team of project leaders supporting the DOT&E Deputy Director for Air Warfare and provided technical support as needed to the Director, OT&E for special interest items. Her analysis portfolio included major aircraft systems such as the F-22, F/A-18E/F, V-22, and H-1 Upgrades. She also evaluated unmanned aerial vehicles such as the Global Hawk, Predator, Shadow, and Hunter UAV systems. Earlier, Dr. Warner worked at the Lawrence Livermore National Laboratory in the laser materials group and as a research chemist at IBM Corporation in San Jose, California.

Dr. Warner grew up in Albuquerque, New Mexico, attended the University of New Mexico as an undergraduate, and earned both bachelor of science and master of science degrees in chemistry from San Jose State University. She earned both master of arts and doctor of philosophy degrees in chemistry from Princeton University. E-mail: catherine.warner@osd.mil

THE T&E OF SYSTEM-OF-SYSTEMS CONFERENCE

## Col. Dave Wellons

commands the Integrated Test and Evaluation Directorate at Fort Bliss, TX

COL Dave Wellons commands the Integrated Test and Evaluation Directorate at Fort Bliss, TX. The Integrated Test and Evaluation Directorate stands as the Army's leading organization tasked with providing an integrated network to the operating force.

COL Wellons recently commanded the Fires Test Directorate at Fort Sill, OK from 2008-2011. During this command, he served as the FOA IX Commander forwarded deployed in Afghanistan in 2010. He conducted 22 field operational assessments ISO U.S. Forces, Afghanistan. LTC Wellons deployed to CENTCOM as chief of plans and deputy commander for 4th Battlefield Coordination Element in support of Operation Iraqi Freedom. After four years in Korea, LTC Wellons assumed command of the Non-Line of Sight Battalion, Unit of Action Experimental Element, at Fort Knox, KY. Following battalion command, Upon completion of battery command, CPT Wellons was assigned to the National Training Center (NTC), Fort Irwin, CA, as Fire Support Officer, 11th Armored Cavalry Regiment. After NTC, he attended Command and General Staff College and School of Advance Military Studies (SAMS). Following graduation from SAMS, he completed a tour as a plans officer at 2d Infantry Division (Uijongbu, South Korea), followed by assignment as executive officer in 6-37 MLRS Battalion and a 2-year joint plans officer assignment in CJ35.

THE T&E OF SYSTEM-OF-SYSTEMS CONFERENCE

# Systems Engineering the New Paradigm

*January 2012*

RIPE for A Systems Engineering Assessment

**Network Integration Evaluation of the "The Army's Tactical Network"**

**A network is composed of "N" nodes, each context-sensitive (implicitly inter-affecting other nodes). Visualization will entail tools for depicting continuous, mutual morphing in pursuit of satisfying Commander's Intent.**

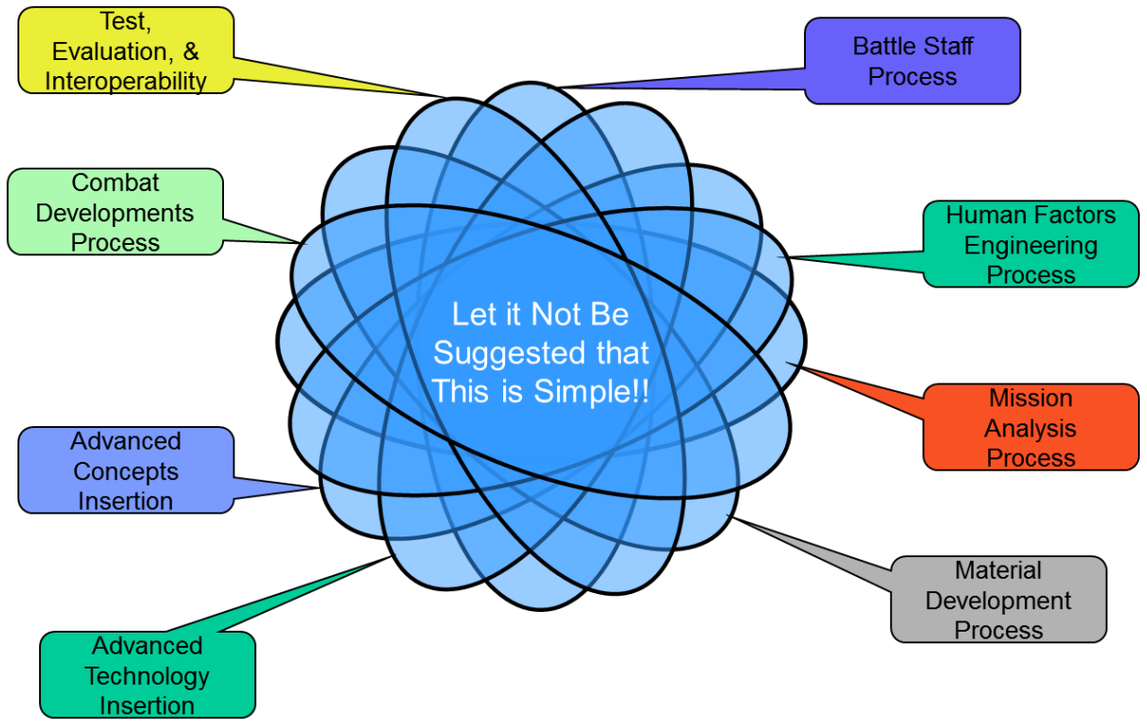



# What Defines a Warfighting Solution

- **Doctrine**: the way we fight, e.g., emphasizing maneuver warfare combined air-ground campaigns.
- **Organization**: how we organize to fight; divisions, air wings, Marine-Air Ground Task Forces (MAGTFs), etc.
- **Training**: how we prepare to fight tactically; basic training to advanced individual training, various types of unit training, joint exercises, etc.
- **Materiel**: all the "stuff" necessary to equip our forces, that is, weapons, repair parts and supplies, etc. so they can operate effectively.
- **Leadership and Education**: how we prepare our leaders to lead the fight from squad leader to 4-star general/admiral; professional development.
- **Personnel**: availability of qualified people for peacetime, wartime, and various contingency operations
- **Facilities**: real property; installations and industrial facilities (e.g. government owned ammunition production facilities) that support our forces.



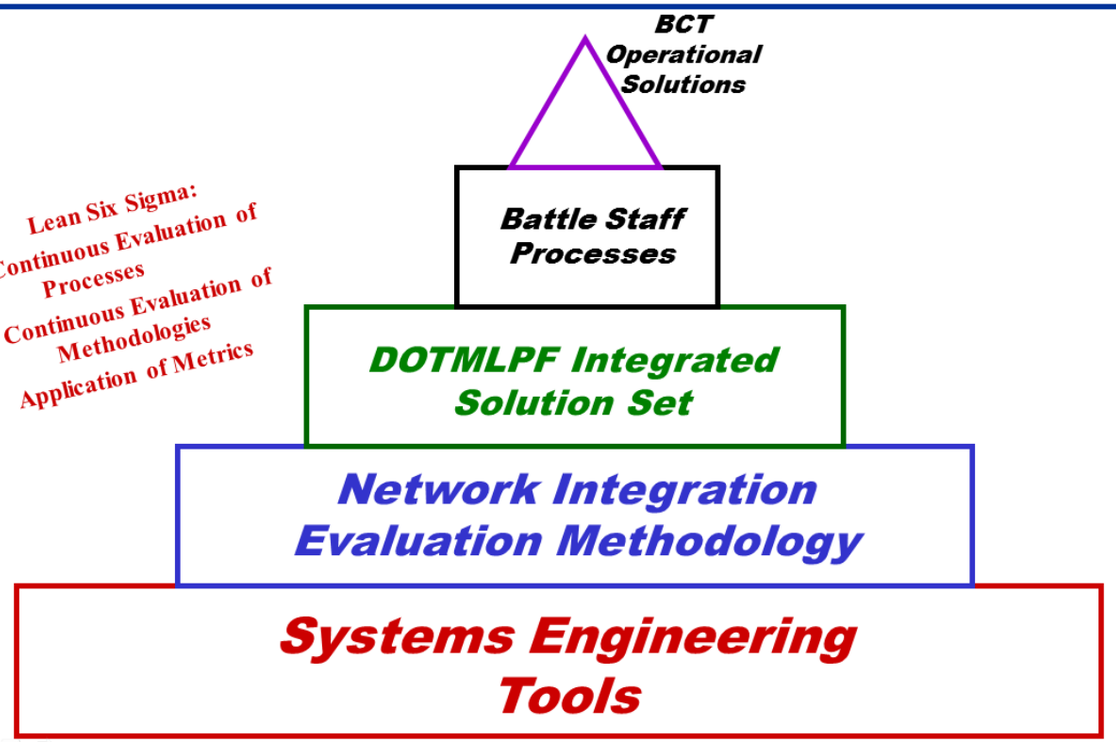

# NIE Process Integration







# Foundations For Warfighting Solutions For BCTs



# Bob Kohout
## How would T&E work for emergent systems?

**Vice President of Research**
iRobot
Public Company; 201-500 employees; IRBT; Defense & Space industry
December 2011 – Present (4 months) | Bedford, MA
Recommend Bob's work at iRobot

**Program Manager**
DARPA/ IIO
August 2008 – December 2011 (3 years 5 months)
Recommend Bob's work at DARPA/ IIO

**Research Scientist**
Strategic Analysis Incorporated
Privately Held; 201-500 employees; Defense & Space industry
September 2004 – August 2008 (4 years) | Arlington, Va
Recommend Bob's work at Strategic Analysis Incorporated

**Sr. Research Scientist**
GD-AIS / Veridian / Pacific-Sierra Research
1999 – 2004 (5 years) | Rosslyn, Va
Recommend Bob's work at GD-AIS / Veridian / Pacific-Sierra Research

**Research Scientist**
Intelligent Automation, Inc.
Privately Held; 51-200 employees; Think Tanks industry
March 1997 – May 1999 (2 years 3 months) | Rockville, Md
Recommend Bob's work at Intelligent Automation, Inc.

**Graduate Research Assistant**
University of Maryland, College Park
Educational Institution; 10,001+ employees; Higher Education industry
1990 – 1996 (6 years)
Recommend Bob's work at University of Maryland, College Park

CALO was an artificial intelligence project that attempted to integrate numerous AI technologies into a cognitive assistant. CALO is an acronym for "Cognitive Assistant that Learns and Organizes". The name was inspired by the Latin word "calonis," which means "soldier's servant". The project started in May 2003 and ran for five years, ending in 2008.

The CALO effort has had two major spin-offs, the Siri intelligent software assistant that is now part of the iOS 5 in the iPhone 4S, and the Trapit project, a web scraper that makes intelligent selections of web content based on user preferences.

# Observations

- Program Managers decide how much and where DT is done
  - Often contractor DT not as realistic as government DT and many times it has far greater limitations
  - Can be a recipe for failure – system less prepared for IOT&E
- Developmental testing has not been sufficient or adequate
  - OT&E results indicate a Department-wide problem
  - Seeing more weapons systems not ready for IOT&E and combat.
  - Congress recently created a Director of Developmental Test and Evaluation
- DOT&E is concerned with mission accomplishment, demonstrated performance, in an operationally realistic environment versus a realistic threat.
- Today, the operationally realistic environment is **JOINT**.

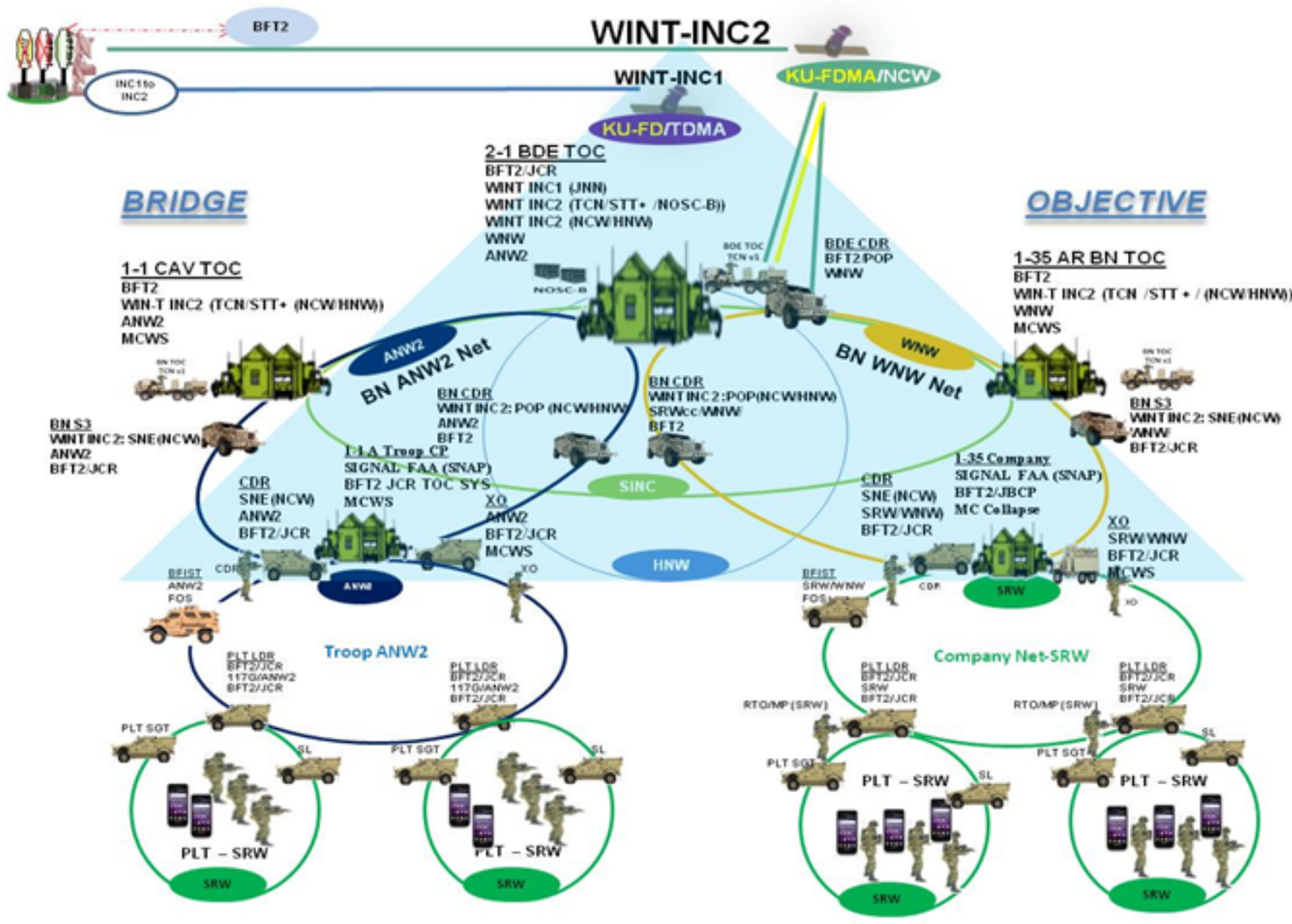
# Suggestions for SE and T&E Communities

- Do not skimp on prototypes or LRIP items – major issue
- DT generally does not focus on identifying operational consequences of weapon system performance
- Realistically stress a weapons system in developmental testing – operational testing to confirm
- Understand rationale for requirements and KPPs, but do not regard them as inviolate
- Comparative or baseline test and evaluation protects the program
- Test against a realistic, living, breathing threat intent on winning – *the enemy has a vote*

# The Network

**"The Network…is the Army's Number One Modernization Effort."**

**- 2011 Army Posture Statement**




- *The Network is Essential to a 21st Century Expeditionary Army*

- *Enables Awareness and Understanding for Leaders Who Must Act Decisively Across the Range of Military Operations*

- *Essential for Joint, Coalition & Interagency Planning and Operations*

- *The Solution - to Provide a True Enterprise Network, Completely Integrated and Interoperable from the Highest to the Lowest Echelons*

- *Evaluate, Integrate and Deliver Network Systems and Capabilities Incrementally; Aligned the Delivery of the Systems With the ARFORGEN Process*

# The Army Agile Capabilities Life Cycle

(aka "Agile Process")

6 Months

DP1 — 1-2 Star GOSC

DP2 — 1-2 Star GOSC

DP3 — GOSC/AR2B/CDRT

| Phase 0 | Phase I | Phase II | Phase III | Phase IV | Phase V | Phase VI |
|---|---|---|---|---|---|---|
| Define Gaps and Near Term Requirements<br>Lead: TRADOC | Solicit Potential Solutions<br>Lead: ASA/ALT | Candidate Assessment<br>Lead: SOS-I | Evaluation Preparation<br>Lead: BMC | Integration Rehearsal<br>Lead: SOS-I | Integration Evaluation<br>Co-Lead: BMC ATEC | Implementation Plan<br>Lead: ARSTAF |

Network Evaluation TRIAD

ATEC Lead for OT

Network Evaluation TRIAD

DP 1 - Viable Candidate List
DP 2 - Candidates Selected for Evaluation
DP 3 - Baseline Insertion

**Execute within Allocated Budget**

**Make fielding decisions 6 months after the identification of capability solution candidates**

Battle Ready

# FY 11-12 Integrated Evaluation Schedule
## Network Maturation Over Time

U.S.ARMY

NETWORK INTEGRATION TRIAD

APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN

Train/ Ready | Available | Train/ Ready | Available | Train/ Ready | Available | Reset | Train/ Ready | Available | Train/ Ready

BN HQ HWI/SWI Int, Technical Commex, Delta NET, Dp Commex

Company NEF & NET

2/1AD gets WIN-T Inc. 2 EDMs TCNs/ PoPs /SNEs

All: HWI/SWI Int, Technical Commex, Delta NET, Dp Commex

**Network Integration Evaluation 11.2**
- MSS LUT
- JCR LUT
- NIK LUT
- HMS MP LUT
- SPIDER LUT
- ONS Systems
- Developmental Network Systems
- TPE Network Systems
- Developmental Systems
- NIR

Individual Training

**Network Integration Evaluation 12.1**
- GCSS-A IOTE
- RR IOTE
- Emerging Systems
- Developmental Systems
- Emerging Network Systems
- Developmental Network Systems
- NET/NEF
- NIR

Collective Training

**Network Integration Evaluation 12.2**
- WIN-T Inc.2 FDTE
- WIN-T Inc.2 IOTE
- HMS MOTE
- JENM IOTE
- ONS Systems
- Capability Set 13 Network Assessment
- NET/NEF
- NIR

Collective Training

**Network Integration Evaluation 13.1**
- ONS Systems
- All BCT Network Systems
- Shadow
- Aerial Tier Bridge
- NETT Warrior IOTE
- APMI LUT
- Gray Eagle -FOT
- SPIDER IOTE
- NET/NEF
- NIR

NIE | NIR | Trng | Network Evals | Capability Evals

Aligned Individual POR Developmental Testing

Includes Emerging Systems; Initial Network Architecture Baseline

CS 13-14 Integrated Network Architecture Baseline

First Unit Equipped

**Increasing Industry NIE Participation**

**Full Industry Participation**

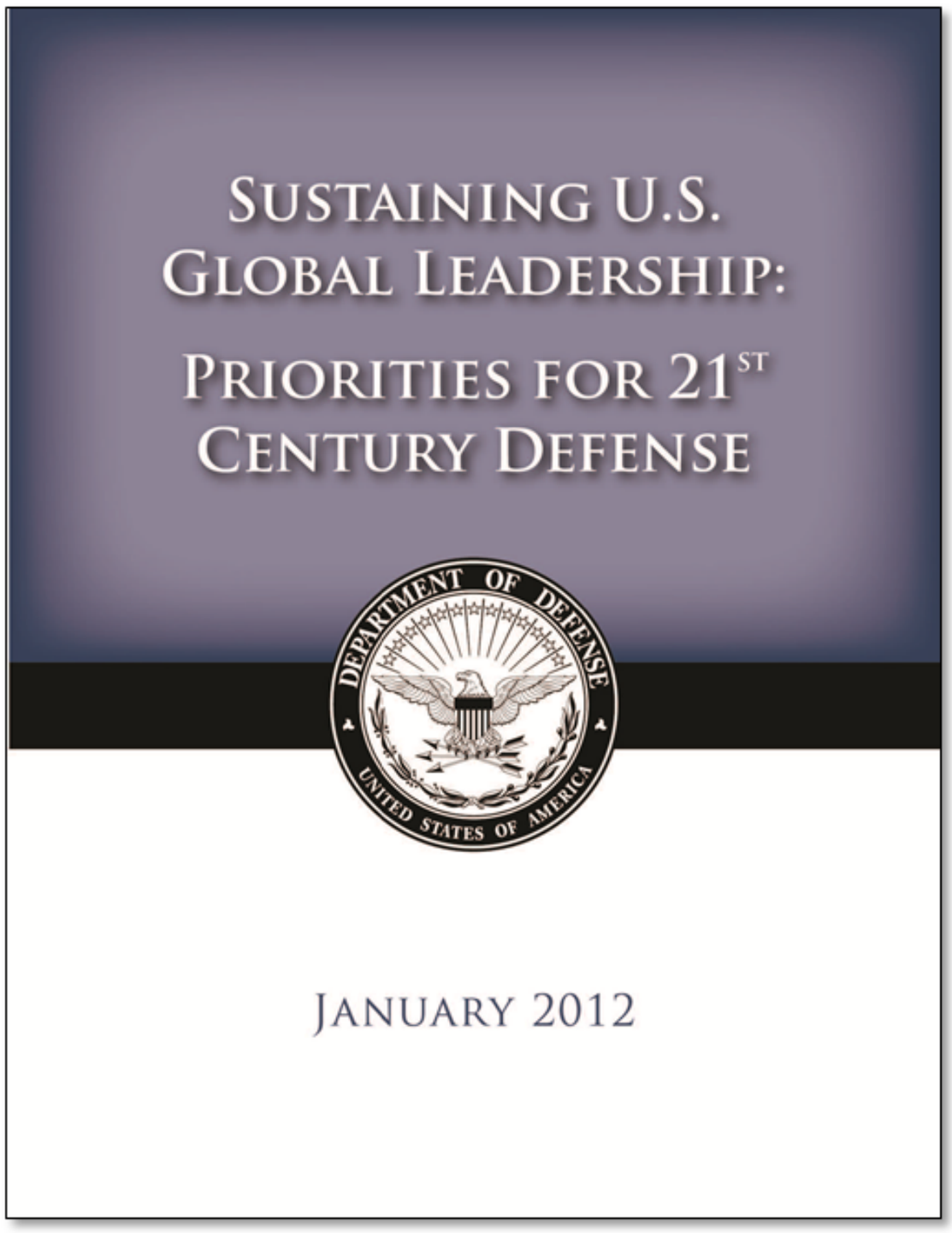
# *Partnering with the T&E Community to Ensure the Relevancy of T&E to 21st Century Defense*

Derrick Hinton
Principal Deputy Director
Test Resource Management Center

25 January 2012

ITEA White Sands Chapter
The T&E of System-of-Systems Conference

# Defense Strategic Guidance
## *Primary Missions of U.S. Armed Forces*



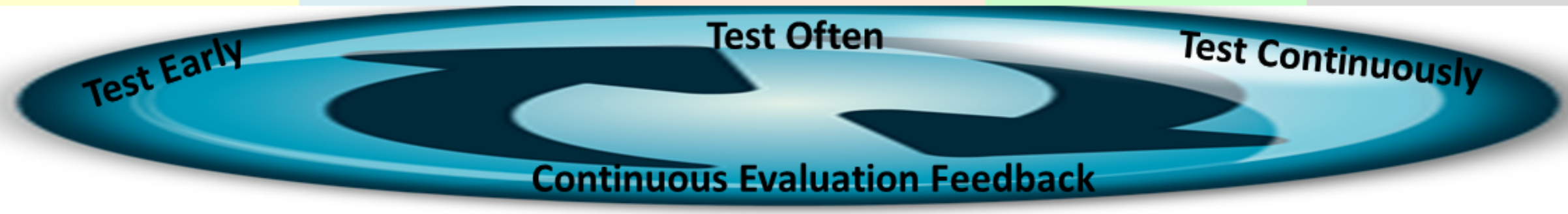

1) Counter-Terrorism and Irregular Warfare
2) Deter and Defeat Aggression
3) Project Power Despite Anti-Access / Area Denial Challenges
4) Counter WMDs
5) Operate Effectively in Cyberspace and Space
6) Maintain a Safe, Secure, and Effective Nuclear Deterrent
7) Defend the Homeland and Provide Support to Civil Authorities
8) Provide a Stabilizing Presence
9) Conduct Stability and Counter-Insurgency Operations
10) Conduct Humanitarian, Disaster Relief, and Other Operations

# How Do We Make This a Reality?

| A | B | C | | |
|---|---|---|---|---|
| **MATERIAL SOLUTION ANALYSIS** | **TECHNOLOGY DEVELOPMENT** | **ENGINEERING & MANUFACTURING DEVELOPMENT** | **PRODUCTION & DEPLOYMENT** | **OPERATIONS & SUPPORT** |
| Material Development Decision | | Post CDR-A | FRP Decision Review | |
| T&E Strategy | TEMP | | | |
| | | Assessment & Test Reports | | |

***Push T&E Earlier – Use Distributed LVC T&E***

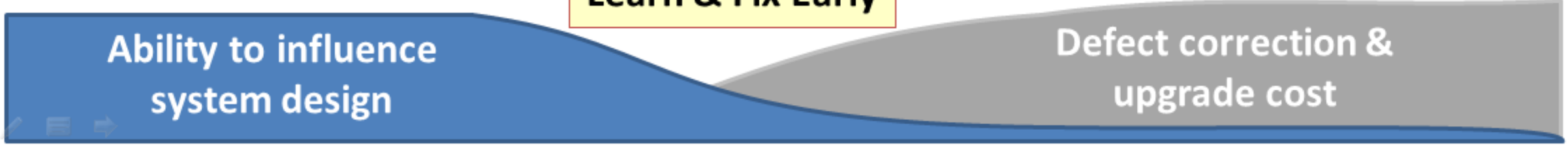
| | | | | |
|---|---|---|---|---|
| **T&E Activities:** | **T&E Activities:** | **T&E Activities:** | **T&E Activities:** | **T&E Activities:** |
| • Rqmts Testability Review | • Design OA | • Lab-Based M&S DT&E / EOA | • OAs | • OAs |
| • Mission/Functional Analysis | • ACTD/ATD | • Safety DT&E /EOA | • LUFT | • OT&E |
| • Joint Experimentation/ACTD | • RAM Analysis & Testing | • RAM DT&E / EOA | • IOT&E & IOP T&E | • User Feedback |
| | | • Conf T&E for IOP /DT&E | • LFT&E | • Operational Caps & Lims |




Test Platform — Test System — Test SoS

**RISK IDENTIFICATION…** → **MISSION CAPABILITY VERIFICATION…**

**Learn & Fix Early**



# Defense Strategic Guidance
## *T&E Takeaways*

- **Key T&E Attributes for the 21st Century**
  - Agile
  - Responsive
  - Efficient
  - Effective
  - Persistent, Distributed Test Infrastructure
  - Focus on Assessment of Military Capability
  - Robust Testing of Networked Warfare and Cyberspace
  - Aggressive Investments in T&E/S&T and new Test Capabilities
  - Test the System-of-Systems with the Goal of Testing the Mission

***Test Early – Test Often – Test the Mission***

# Add T&E Instrumentation & Networks

## Range Information Grid

Bidirectional Secure Range Network

SPECTRUM, LAND, SEA AND AIR RESOURCES

OTHER RANGES

CEC

Unmanned Systems & Networks

TAC NET

C2 CONTROL NET

C4I Providers

Mobile Apps & Adaptive Networks

Joint Task Force

Range Control Facility

*International Test & Evaluation Association*

**Test and Evaluation of Systems-of-Systems Conference**

*January 24-27*

*El Paso, Texas*

# A Panel on Systems-of-Systems Testing and How Distributed Testing May Be Used


***Chip Ferguson***

**Program Manager**

**Joint Mission Environment Test Capability**


**January 25, 2012**

**1330-1500**

# What is Distributed Testing?

- **A persistent and continuous process of linking various geographically separated live, virtual, and constructive sites and capabilities together in a distributed environment, across the acquisition life cycle to support and conduct the test and evaluation (T&E) of a system or systems-of-systems.**

**A new way of thinking for many in the Test and Evaluation Community**

# 2012 Panel Overview

- Colonel Dave Wellons, USA, Director, Integrated Test & Evaluation Team, Ft Bliss, TX
- Mr. Byron Baker, Chief, C2 Battlespace Awareness Portfolio, Joint Interoperability Test Command/Joint Interoperability Testing
- Mr. Darrell Schultz, MAGTF Command and Control, Weapons and Sensors Development and Integration, System Integration Team, Marine Forces Systems Command
- Lt Col Earl “Skip” Stolz, Commander, 46 Test Squadron, Eglin AFB, FL

# Network Integration Evaluation

## What is the NIE?

***The Network Integration Evaluation (NIE) is a series of semi-annual evaluations designed to integrate and mature the Army's tactical network.***

- Conduct **integrated and parallel Operational Tests** of select Army programs of record.
- Evaluate development and **emerging network capabilities** in an operational environment.
- Assess **non-networked capabilities** in an **integrated operational environment**.




***It's a new way of doing business –***

***a fundamental change in how we deliver capabilities to our Soldiers***

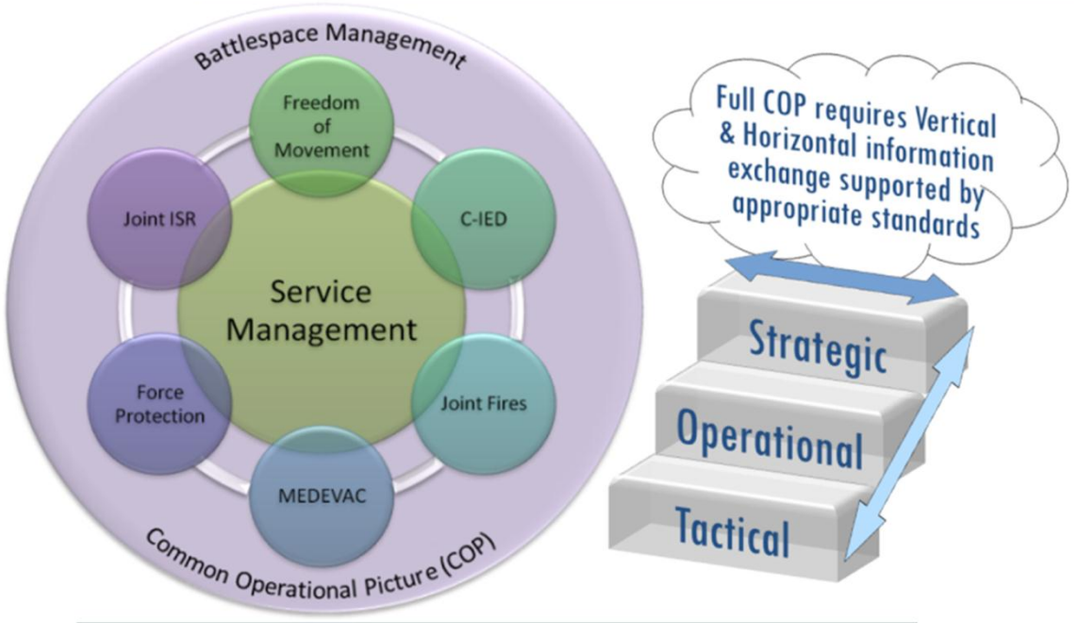
# Network Integration Evaluation

## What Makes the NIE Different?

***The "Adaptive" Evaluation Concept:***

- –**Integrated** evaluations of capabilities **rather than discrete** evaluations
- –Synchronized and consolidated feedback loop – **two evaluations per year**
- –Evaluation and integration from **Platoon to BCT** levels
- –Tactical environment covering **12,000 sq. km of complex terrain and airspace**
- –Includes opportunities for **integrating industry solutions and emerging technologies** in parallel
- –Established a **network baseline for incremental modernization**
- –**The Business Case: Reduced costs thru efficiency & competition, quicker cycle times, and rapid technology insertions**

# Mission Thread Interaction

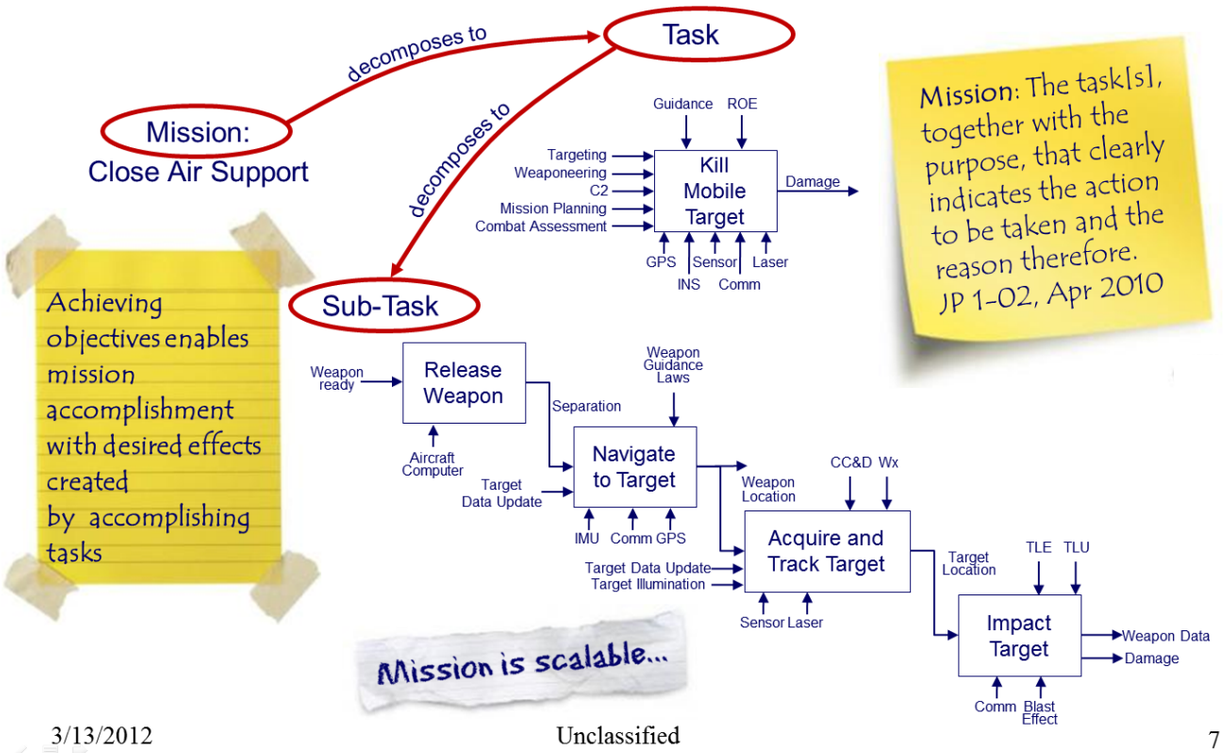



One mission thread is not independent of the others and each drives the other threads in various ways





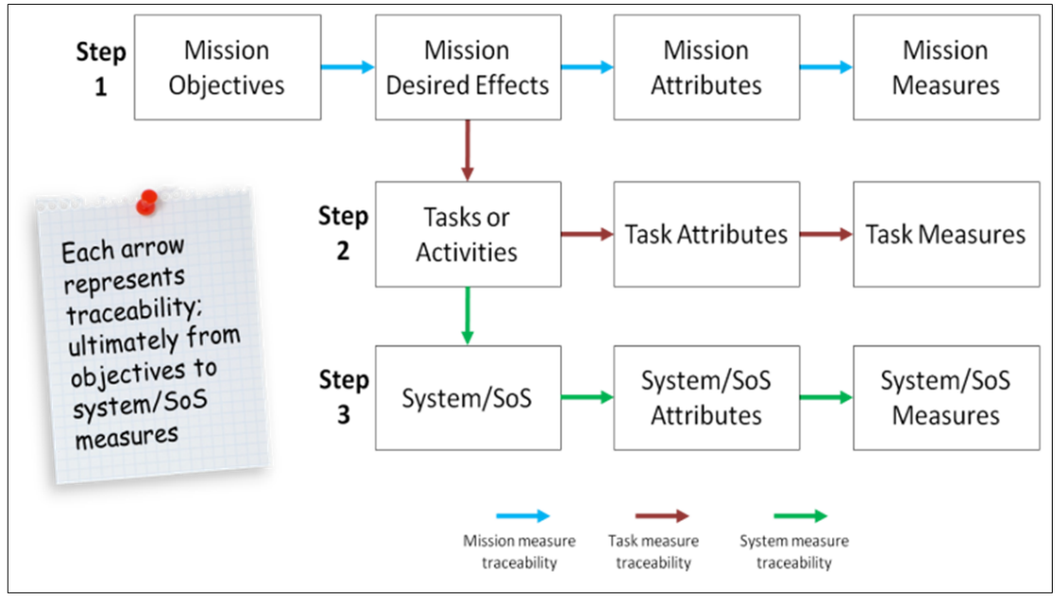
# Mission Decomposition








# Measures Development

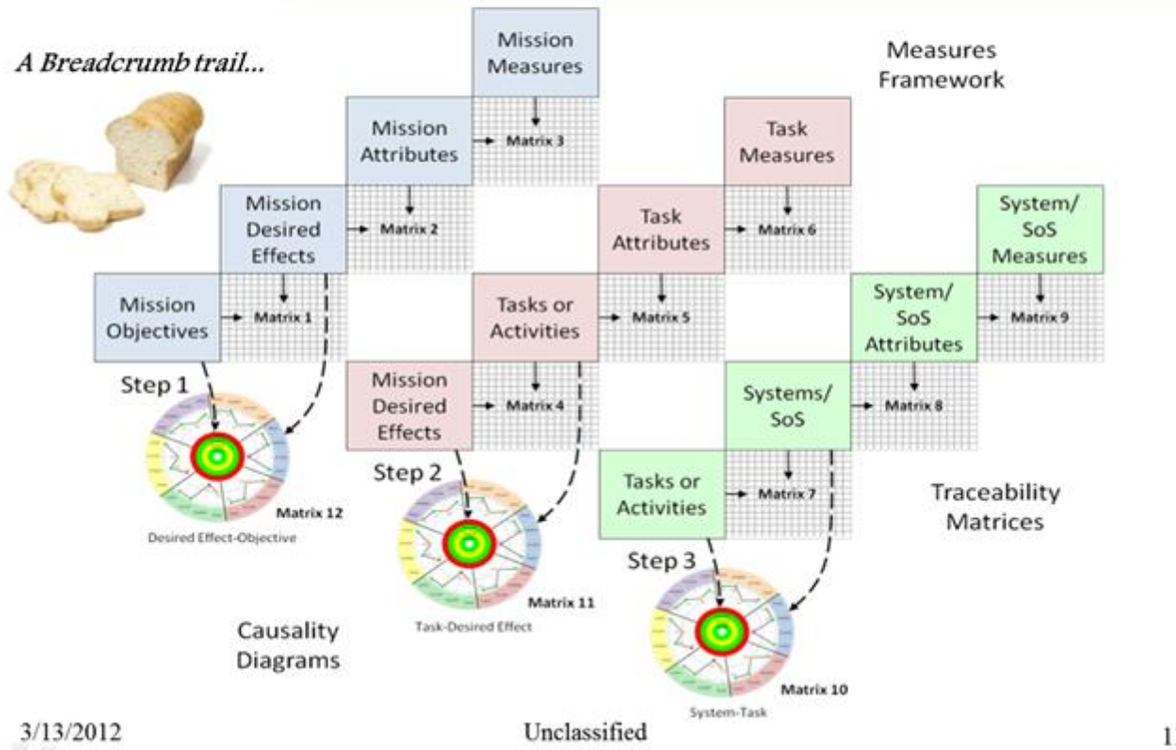



**Mission Thread Analytic Framework**





# Mission Thread Analytic Framework



# ITEA: The T&E of System-of-Systems Conference:

## Test As You Operate Panel

**Kevin Knudsen**

January 25, 2012




Engineering, Operations & Technology
Boeing Test & Evaluation

**Mr. Kevin Knudsen**
**Systems/System of Systems Test Capability Leader**
**Boeing Test & Evaluation**

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# Questions Posed to the Panelists



1. What does "test as we operate" mean to your stakeholders with respect to the large-scale systems of systems employed in your organizations' operations?
2. What works?
3. What does it mean for your V&V efforts?
4. What are you doing to improve results?





# Increasing Complexity and V&V

Engineering, Operations & Technology | **Boeing Test & Evaluation**

- Systems of systems are complex, and the complexity increases exponentially.

  How do we
  - Ensure that systems and systems of systems are interoperable?
  - Know when a system of systems meets the end user needs under all actual operational conditions?
- The inherent emergent behaviors (beneficial, neutral, and harmful) arising from systems of systems are difficult to understand, predict, and manage.

  How do we
  - Monitor, manage and respond to emergent behavior and exploit emergent and unintended effects?
  - Detect and then correct critical anomalies?

**Our approach to the V&V of complex systems of systems needs to be revisited.**

# Test-as-We-Operate Focus—An Advantage?



- An expectation during operational testing
  - "Once a system has been **demonstrated in an operationally relevant environment**, it may enter the Production and Deployment phase."–DOD
  - "Address critical issues regarding a system's performance in **combat-like environments when operated by field personnel.**" –AFOTEC
  - "Verify that systems are **operationally effective and suitable for intended use.**"–FAA
- Advantageous during development test?
  - "The **primary purpose of test and evaluation** (T&E) is to support system development and acquisition by serving as **a feedback mechanism in the iterative systems engineering process**."–Army
  - "The **fundamental purpose of test and evaluation** is to provide knowledge to assist in **managing the risks involved in developing**, producing, operating, and **sustaining systems and capabilities**"–OSD

**A test-as-we-operate focus is key to system of systems V&V.**

# COMOPTEVFOR


# System of System Verification & Validation for NextGen Transformation of the NAS

Federal Aviation Administration

Presented To: ITEA SoS Conference

By: Maureen Molz

Date: January 24-27, 2012

## SoS Assurance

John Goodenough

January 2012

Software Engineering Institute | Carnegie Mellon



# ITEA El Paso T&E of SoS Conference

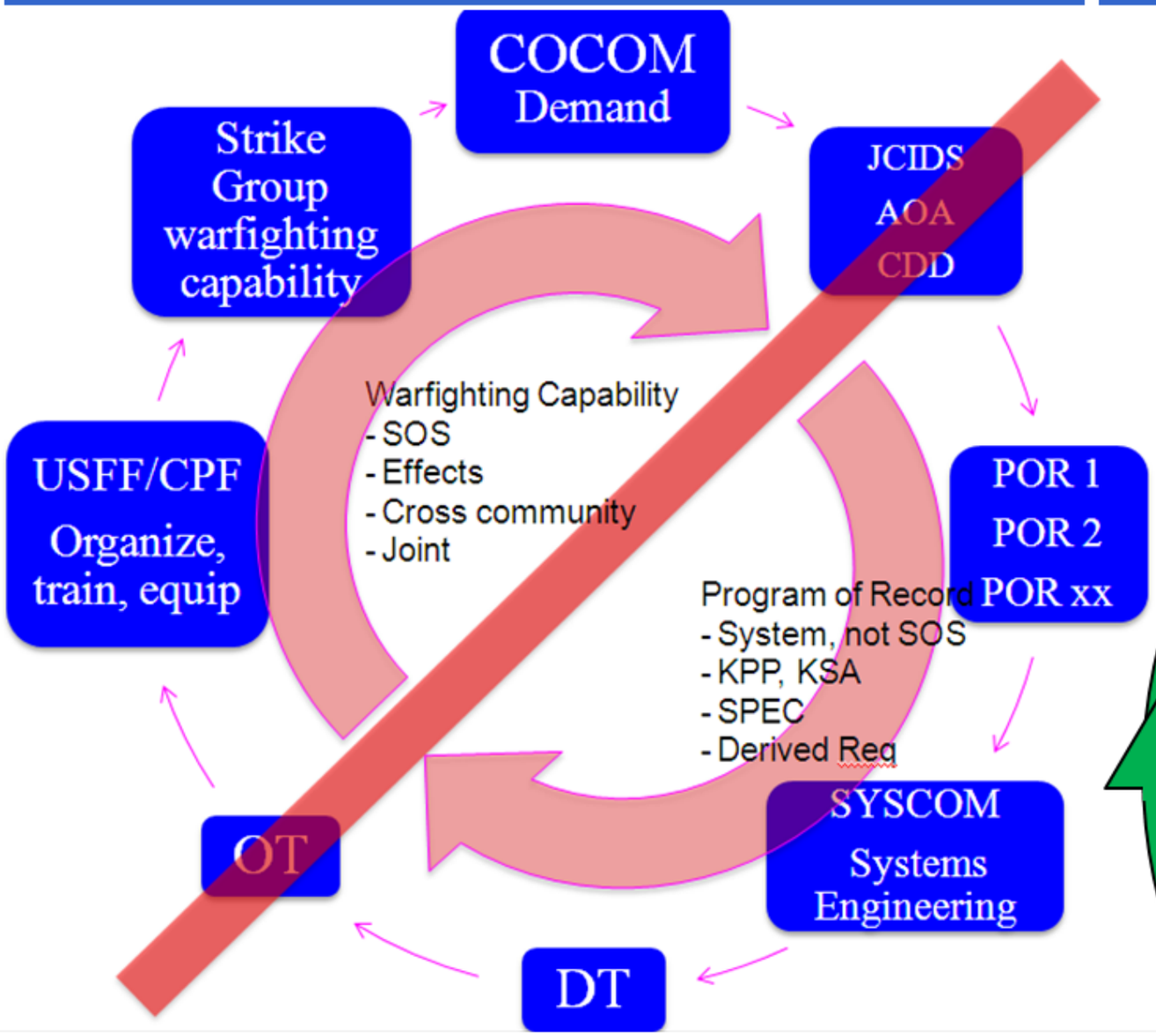
## Test As You Operate Panel

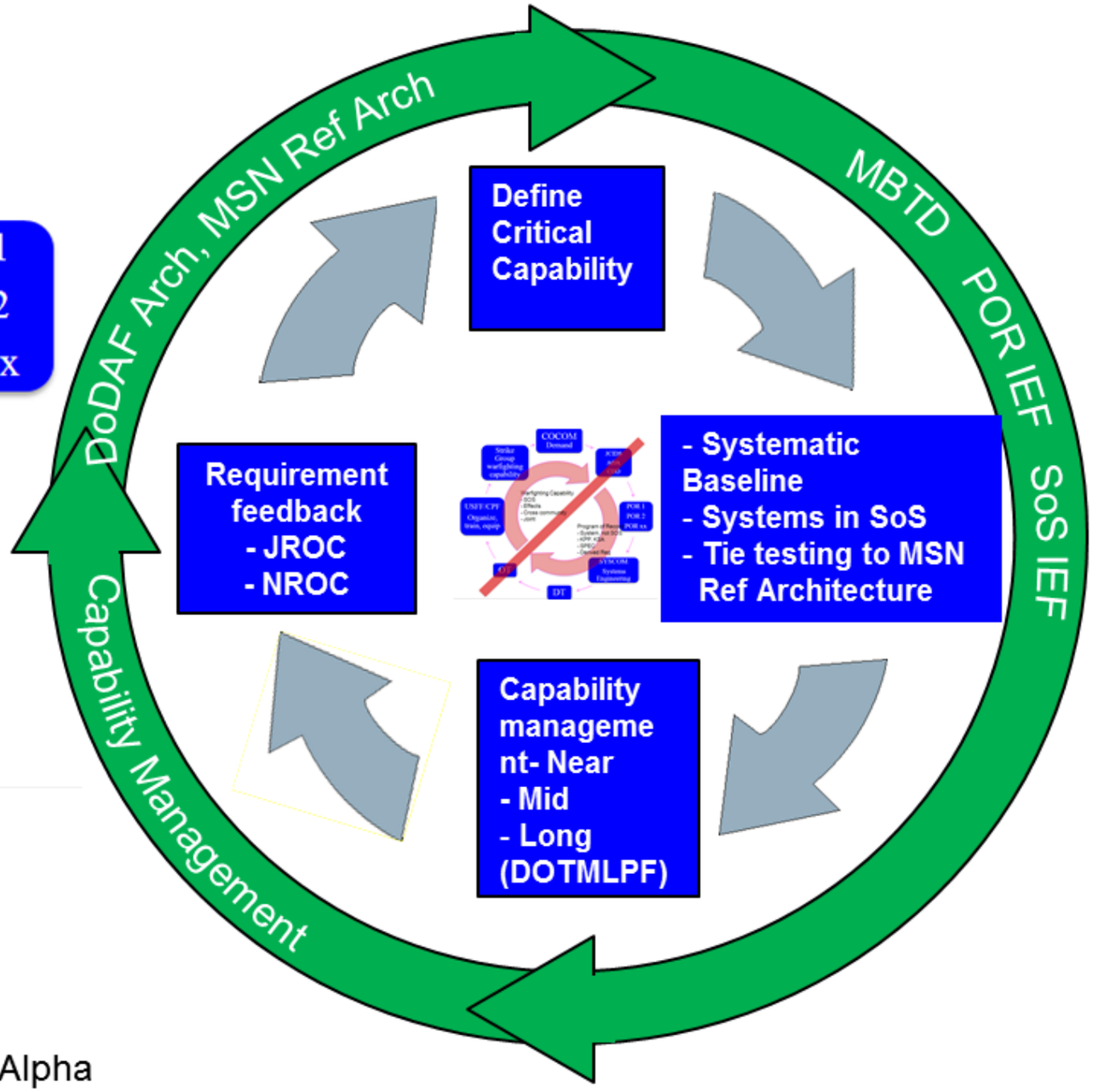
**25 Jan 2012**

LOCKHEED MARTIN

**John Varljen**
**Director, Test Engineering and Chief Engineer**
**Assembly, Test and Launch Operations**
**Space Systems Company**

# Baseline Capability Management Governance



# HOW OT…

Joint Capability Area

Universal Joint Task List

Joint Mission Thread

Capabilities Documents

Technical Decomposition

AoA

System 1 System 2 System 3

Performance Spec

Detailed Spec

Test Design

Test

Analysis

Integrated Test

Operational Decomposition

Mission Task

Mission Task

Mission Task

Task/Subtask

Conditions

Attributes

Data Rqmts

Test

Analysis

System Under Test

Warfighting Effect

# Dr. John Goodenough, Carnegie Mellon



**John Goodenough is a Fellow of the ACM and of the Software Engineering Institute (SEI).**

**He has led a research initiative on system of systems software assurance and was a co-author of a study on "ultra-large-scale" systems.**

**Goodenough was with the SEI for 25 years before retiring in December 2011.**

**He was the SEI's first Chief Technical Officer and before that, led a project that introduced Rate Monotonic Analysis into standard usage in the real-time community.**

**Prior to joining the SEI, he worked at SofTech on Ada language design and validation tests.**

**He has a A.B., M.A., and PhD from Harvard University.**

**jbg@sei.cmu.edu,**
**john.b.goodenough@gmail.com**

http://www.sei.cmu.edu/library/abstracts/books/0978695607.cfm

Dr. John Goodenough, Carnegie Mellon

Engineering, Operations & Technology | **Boeing Test & Evaluation**

## SoS Software Assurance

*Justified* confidence in system and system of systems (SoS) behavior requires software assurance theories and principles that don't exist today. Using such theories and principles, organizations would have a better basis for confidence in deployed system behavior, and at the same time, these theories and principles could be used to make the assurance process more efficient and effective.

The system-of-systems software assurance (SoSSA) research focuses on meeting the assurance needs of large-scale, multi-user adaptive information management and command-and-control systems of systems that will be operated in unanticipated ways.

http://www.sei.cmu.edu/dependability/research/assurance/index.cfm

To make the assurance process more efficient (and effective), we need to answer foundational questions such as the following:

- Which assurance activities provide the biggest increase in justified **confidence** that a system will behave acceptably when fielded?
- Can some assurance activities be **curtailed** without reducing justified confidence in deployed system behavior? For example, when is it reasonable to **stop** testing a system, and why?
- What insights do assurance activities yield into the **residual risks** that are present in a deployed system?
- What evidence is most **probative** in deciding whether a system should be released?
- What is a **principled theoretical basis** for asserting that sufficient confidence has been obtained in software-reliant behavior?
- What types of **justification** are more or less acceptable?
- Is a proposed **confidence level** well justified by sound principles and theories?

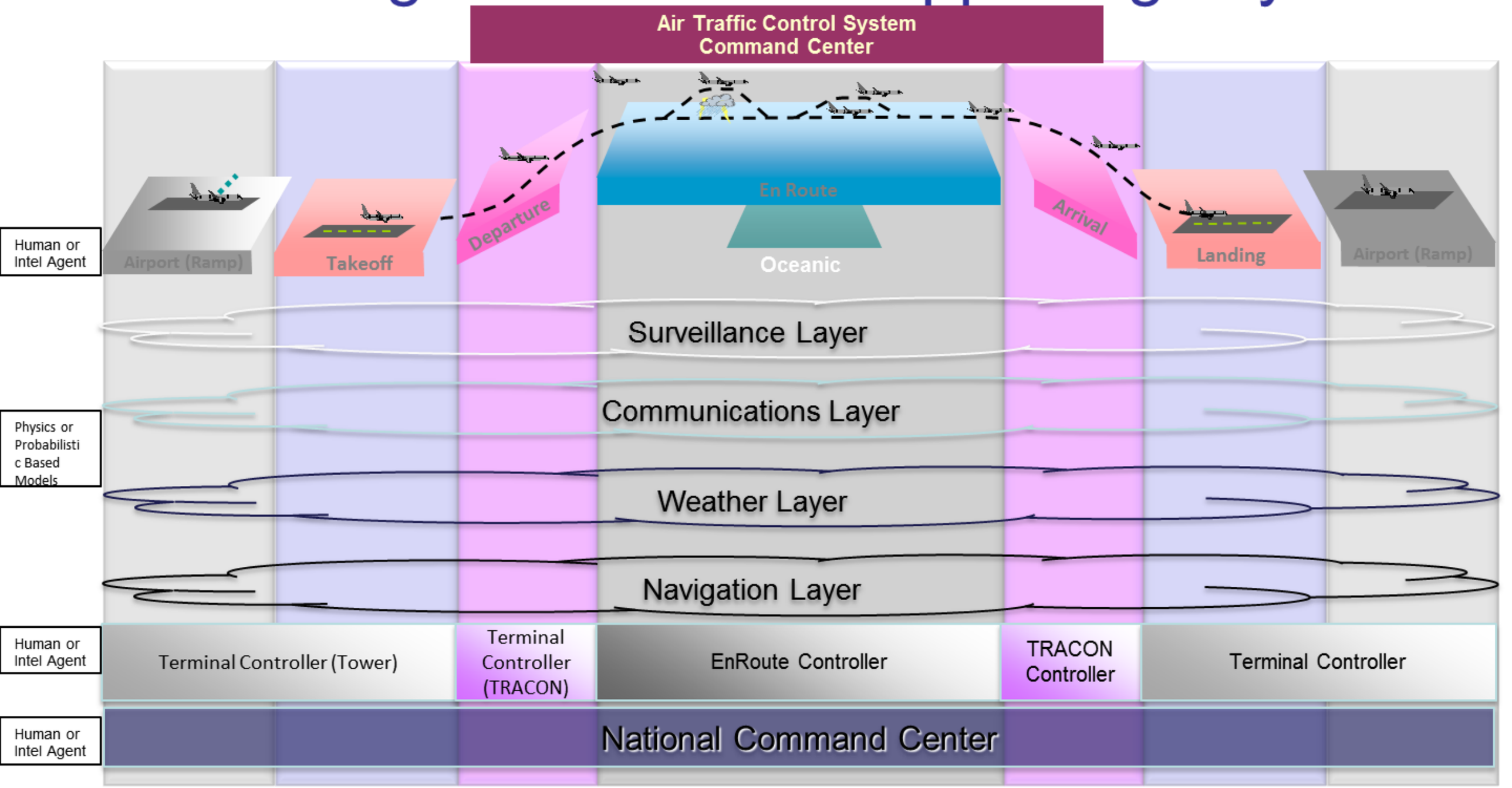
# Dr. John Goodenough, Carnegie Mellon

Engineering, Operations & Technology | **Boeing Test & Evaluation**

**Thrust 1: Assurance Argumentation:** Failure mode, effects, and criticality analysis (FMECA) and fault tree analysis (FTA) are standard techniques used to find design errors in hardware systems. The notion of doing FMECAs and FTAs for software systems has been proposed by others (Haapanen 2002) but given how software systems are architected and documented today, it was never quite clear how to trace out the effects. But a structured argument (demonstrating some property of a system) captures the reasons why the system is believed to work. One could use an FMECA/FTA approach on such an argument structure.

**Thrust 2: SoS Failure Modes:** If we are going to achieve increased confidence in the behavior of a system of systems under all circumstances, we need to understand the ways in which such systems fail, and in particular, the failure modes that are distinct from those of monolithic systems (whose evolution and content is completely under control of a central authority). For example, because SoS constituents evolve independently, it is possible for the collective set of evolutions to gradually degrade some desired overall SoS quality, e.g., end-to-end performance for certain threads.

# NAS Flight Profile and Supporting Layers




346 Towers

21 En Route Centers

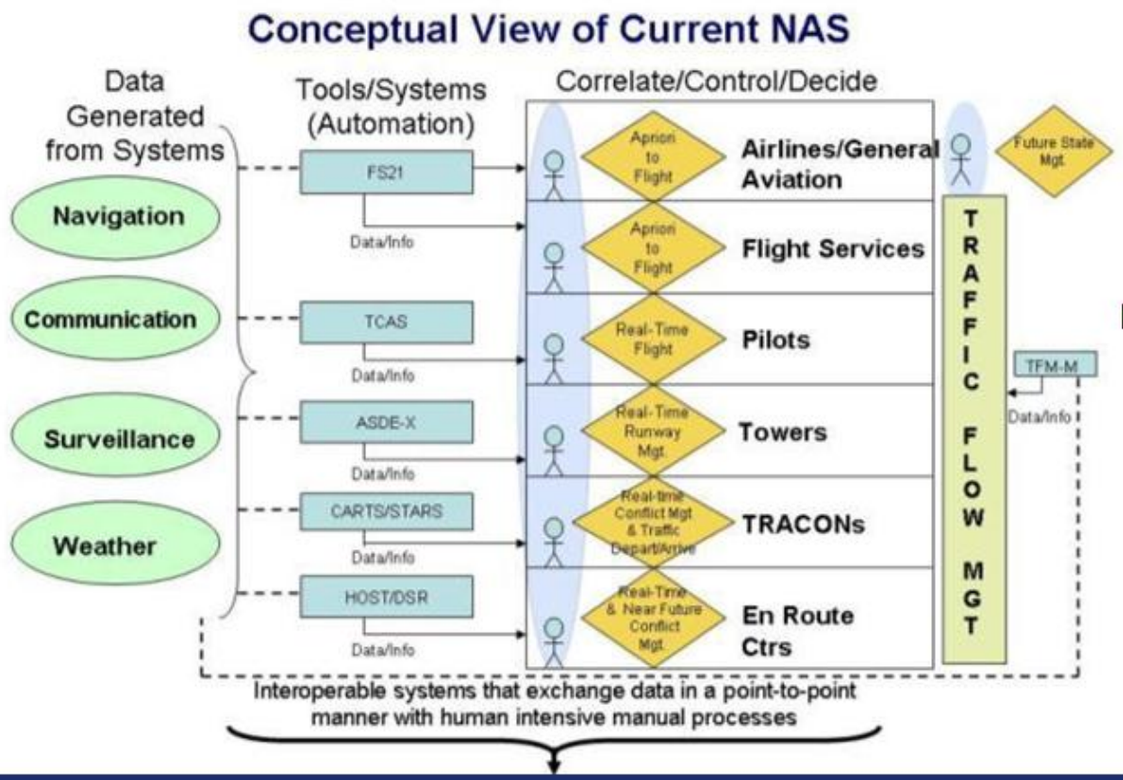
175 TRACONS

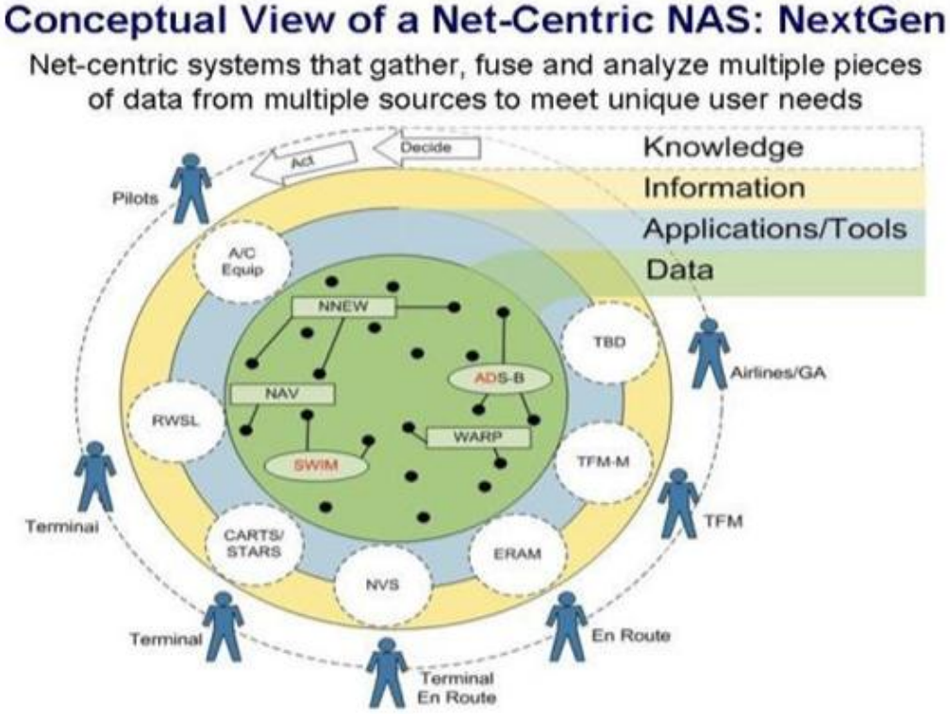
~ 15,000 Total Controllers on Staff

~ 7000 flights/hour – 50,000 flights/day

# NextGen: Improving Efficiency & Capacity

| Today's NAS | | NextGen |
|---|---|---|
| Ground-based Navigation and Surveillance | → | Satellite-based Navigation and Surveillance |
| Air Traffic Control Communications By Voice | → | Routine Information Sent Digitally |
| Disconnected Information Systems | → | Information More Readily Accessible |
| Cognitive-based Air Traffic "Control" | → | Decision Support tools |
| Fragmented Weather Forecasting | → | Forecasts Embedded into Decisions |
| Airport Operations Limited By Visibility Conditions | → | Operations Continue Into Lower Visibility Conditions |
| Forensic Safety Systems | → | Prognostic Safety Systems |
| Focus on major airports | → | Focus on metropolitan areas |
| Inefficient routes & fuel consumption | → | Shorter flight paths; fuel saving procedures; alternative fuels; reduced noise |



# Complex Systems

- Complex systems are systems that are not directly decomposable in the traditional system engineering paradigm.
- Complex systems require understanding of dynamic behavior
- Model based systems engineering is a promising solution because it gives contextual information. Models provide understanding of various degrees of freedom and the interactions.
- Unified modeling language (UML) is possibly a solution along with modeling and simulation tools.

Ref: Aviation week
Nov 1/8, 2010
"Designs for Success" pg 72

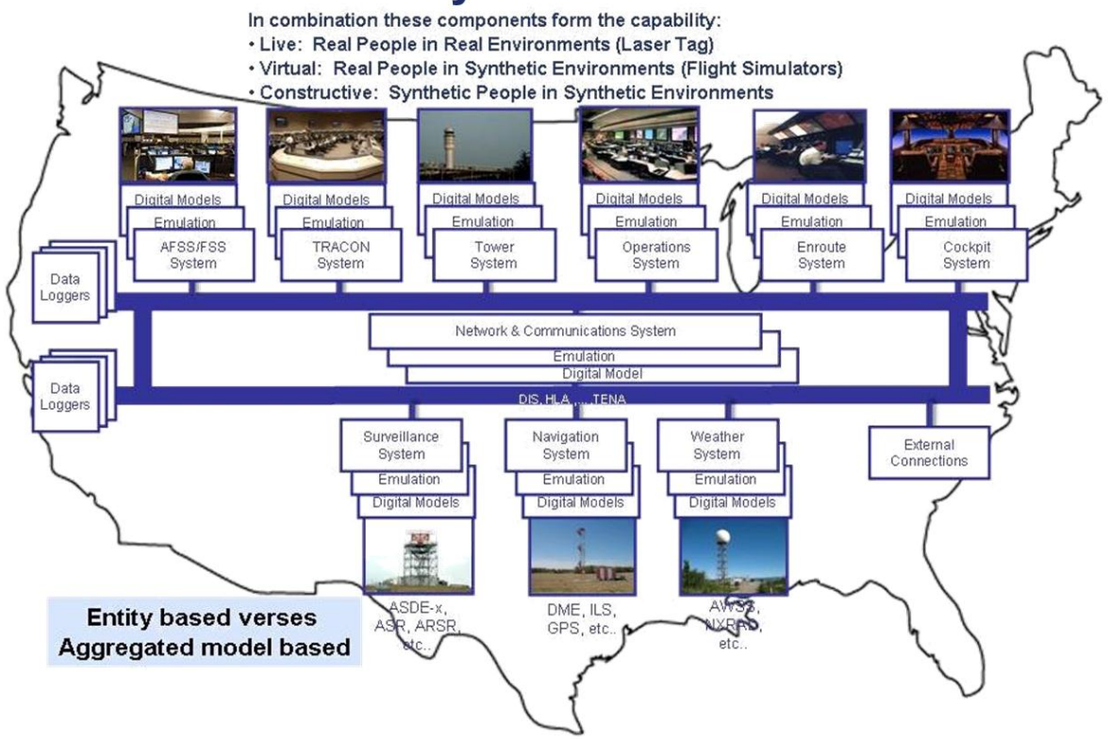


# Approaches to SoS V&V

- Implement good V&V across the FAA Acquisition Management System (AMS)
- Solve the fundamental science issues for complex V&V.
- Develop new System Engineering tools. (ie. New Modeling techniques etc.)
- Build the SoS Assessment Platform to assure we can stimulate the system under test across all of its functional areas simultaneously.

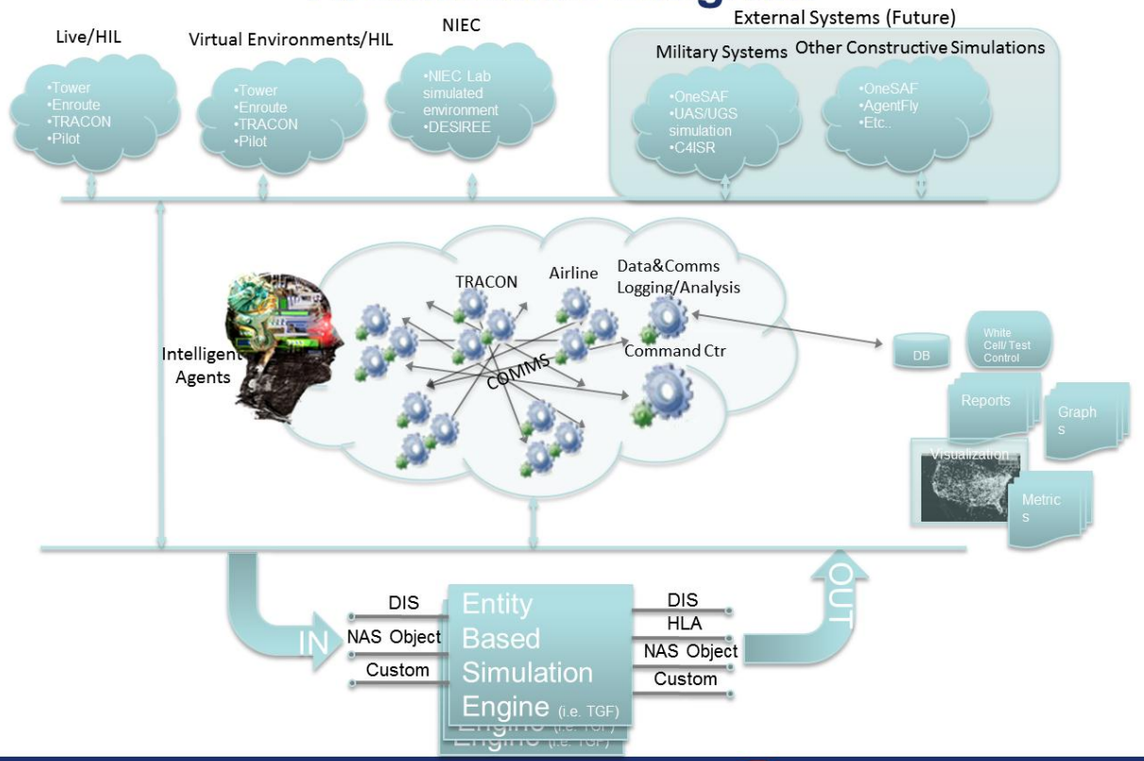


# System of Systems V&V Capability
## NextGen Synthetic Environment



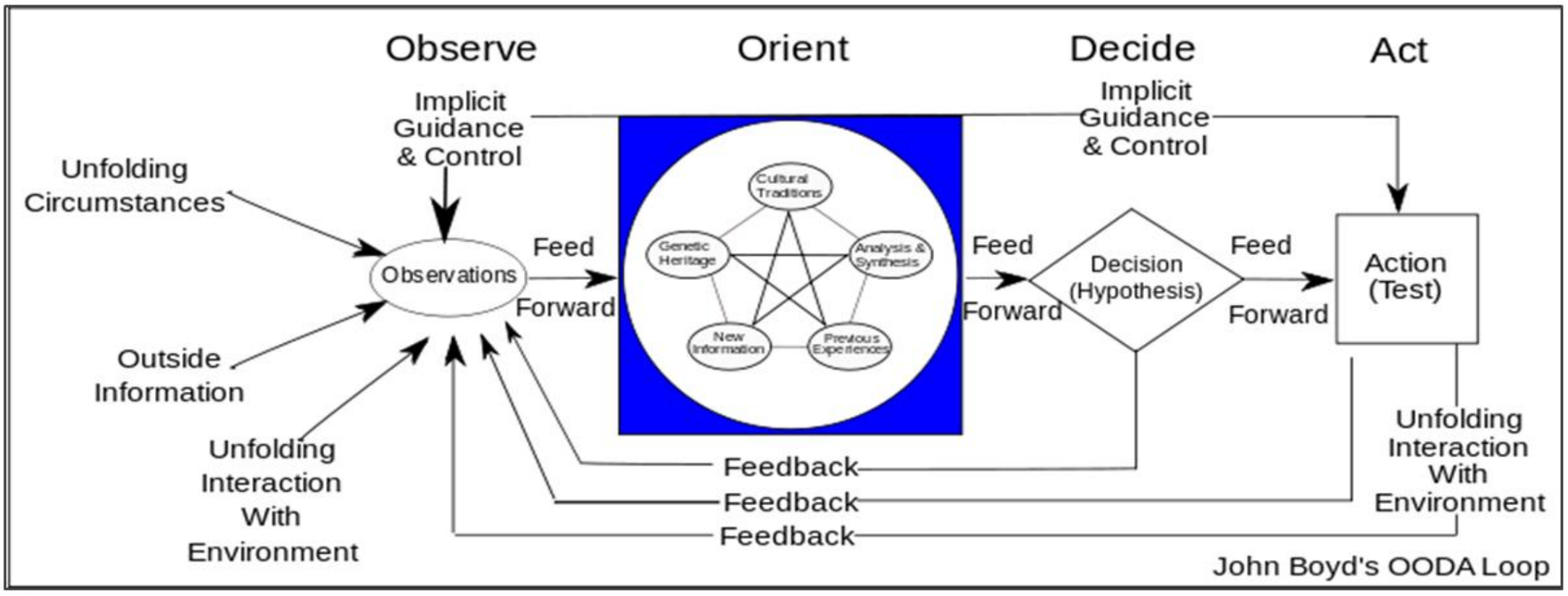



# SoS Assessment Platform
## Architecture Diagram



# OODA, Requirements, Testing

- Opposition's OODA loop is faster than US product life cycle
  - IED's
  - Cyber Warfare
- Thus user requirements change faster than design/production/test
- Test Program's often address yesterday's challenges



# What Works

- SoS "Do not have 'requirements' per se" – Really???
  - Establish ConOps – Update it regularly
    - What?
    - When?
    - How?
    - How much?
  - SE at SoS level provides framework – establish requirements
  - Obtain user feedback
- T&E "grounded" in requirements
- Live test optimal – Is it affordable?
- SoS SE & TE team rep fielded – NRO field reps

# Improving Test as We Operate

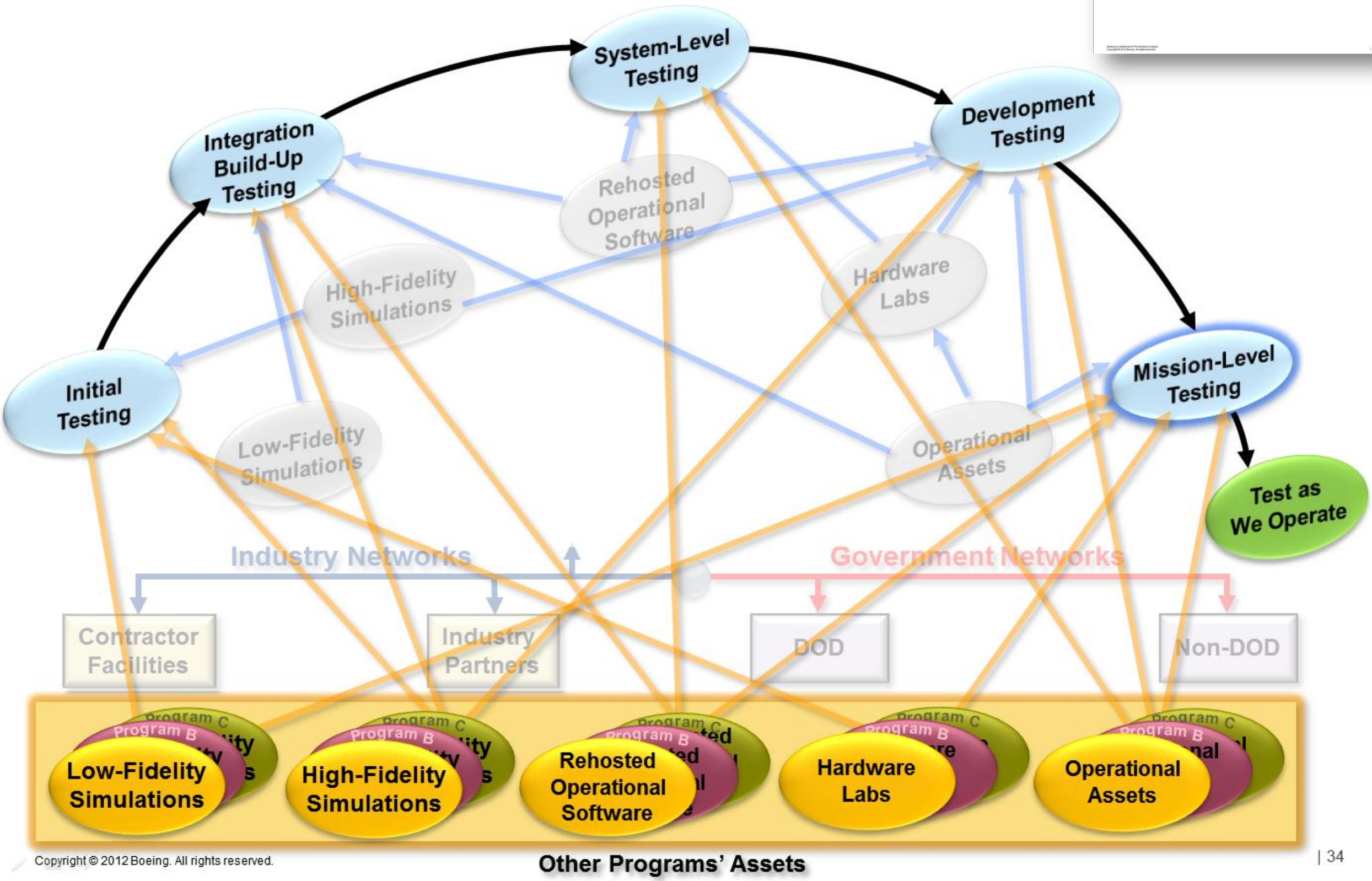
Engineering, Operations & Technology | **Boeing Test & Evaluation**


BOEING
Engineering, Operations & Technology
Boeing Test & Evaluation

**Mr. Jeff Thoman**
**Manager, Integration Test Range**
**Boeing Test and Evaluation**

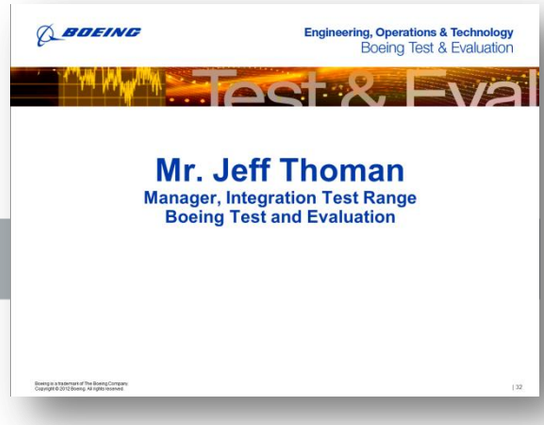




# Industry Perspective: Summary

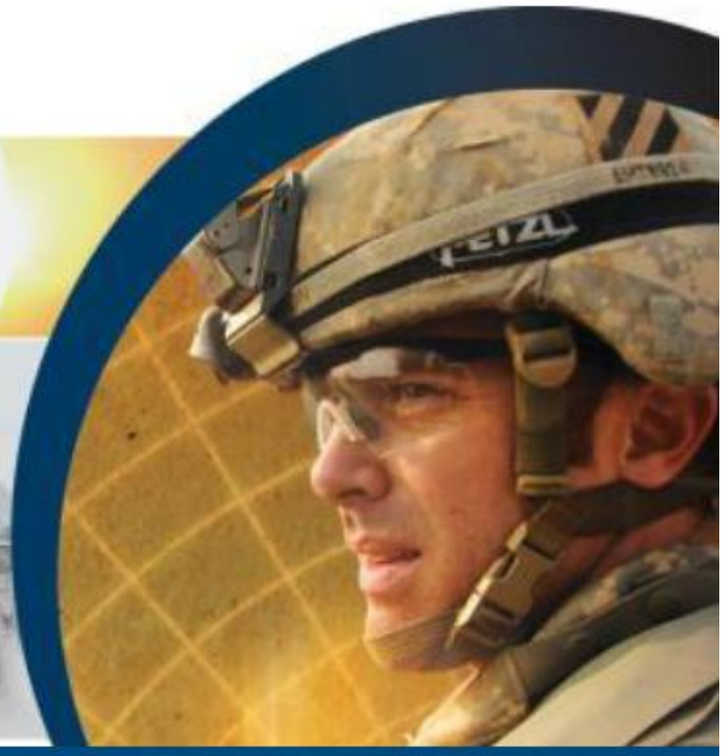





- **To improve test as we operate (fight):**
  - **Keep a mission-level focus across the product test life cycle.**
    - Mission threads
    - Training testers to mission
  - **Ensure the availability of critical assets across programs.**
    - Labs and simulations
    - Integrated networks
  - **Create a relevant complex test environment.**
    - Stimulate SOS under test to drive emergent behavior
    - Understanding of the fidelity of hardware, emulation, modeling & simulation
    - Pedigree of assets across the SOS available throughout test life cycle
  - **Change the test culture to meet complexity of the SOS test.**
    - Influence test-as-we-operate requirements that shape acquisition

~•~

Army Test and Evaluation Command



# How Do You Evaluate the Performance of the Network?

**Mr. David Jimenez**
**Technical Director, Army Evaluation Center**

January 26, 2012

Army Proven
Battle Ready

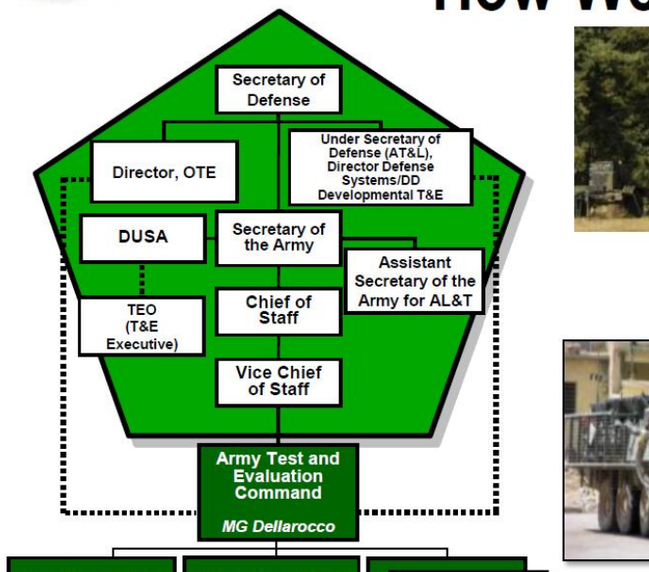
# Where We Are


Army Proven
Battle Ready





# How We Fit




WIN-T

Mine Resistant Ambush Protected (MRAP)

Stryker ICV

Army Proven
Battle Ready





# ATEC - Understand Who We Are

- **Full Spectrum Testing**
  - Only test organization in DoD to encompass all phases of testing; developmental, operational & evaluation
- **Major Contributor to Army / Joint Acquisition**
  - Testing and Evaluating over 500 major systems annually
  - 1100 test events working daily
  - ATEC Forward – Forward Operational Assessment Teams in Iraq & Afghanistan
- **Large, complex organization**
  - Direct reporting agency
  - ~9,800 personnel (72 Ph.D.s) (29 Colonels)
  - 26 Locations, 17 States, Operating on 5.5 million acres (1/3 Army's Land mass), Army's only nuclear reactor
  - Competitive, efficient, operationally-focused, mostly reimbursable
  - $5.1 Billion capital investment in facilities/instrumentation

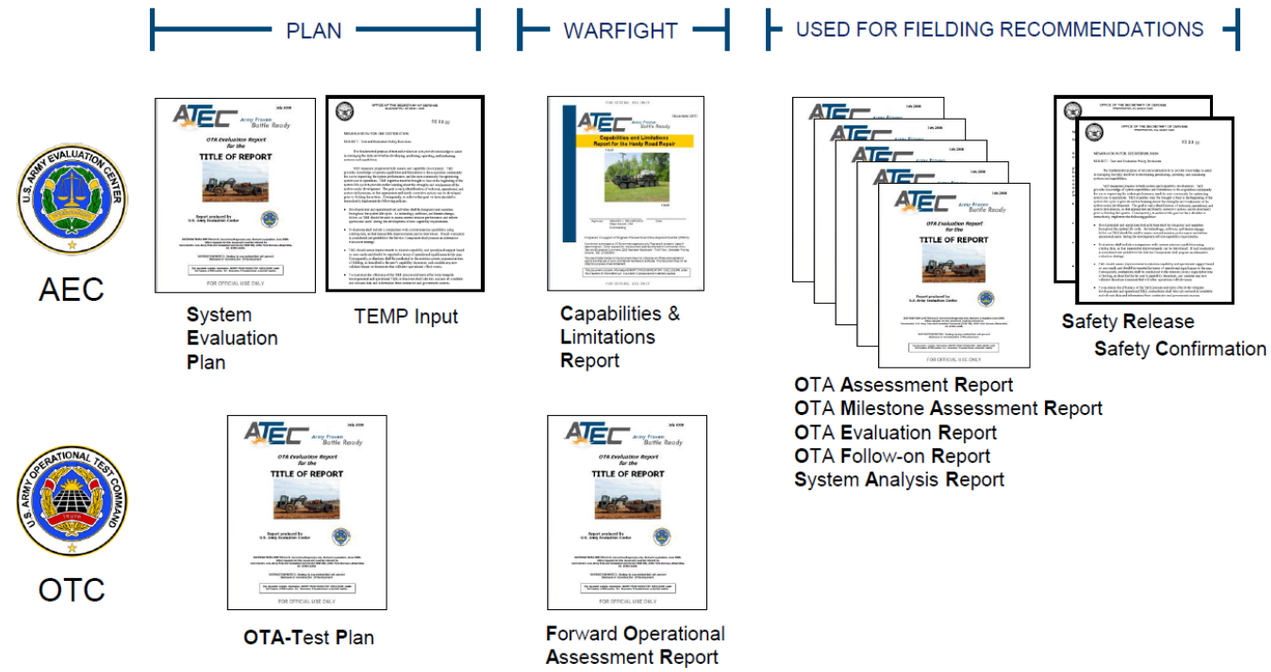
**Testing everything from Rifles ….to National Missile Defense**

Army Proven
Battle Ready





# Products We Produce




Army Proven
Battle Ready

# Major Questions We Answer

**Does it Work?**

**Is it Safe?**

**...How Do I Know?**

EFFECTIVE

SUITABLE

SURVIVABLE



Army Test and Evaluation Command

# Major Questions We Answer

**Does it Work?**

**Is it Safe?**

**...How Do I Know?**

*. . . and is it* INTEROPERABLE



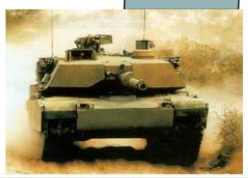
Army Test and Evaluation Command

# System of Systems: Test as We Fight

From

Strategy
Technologies
Resources

To

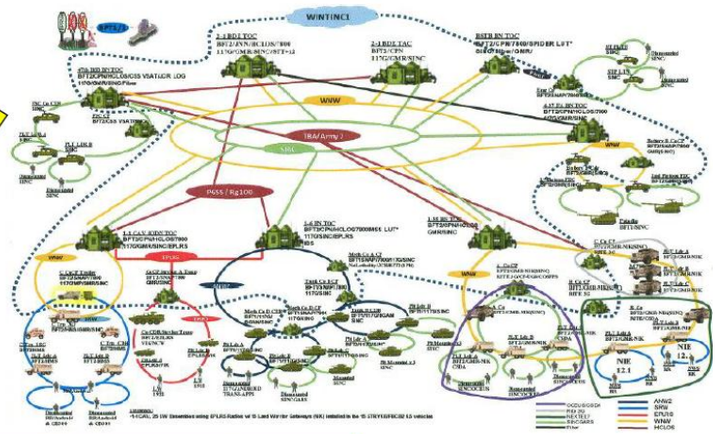


From: Platform Centric Testing…

To: A Network Integration Event
- Entire Brigade in the field

-Located at Ft. Bliss and WSMR

-Testing the Material along with the entire DOTMLPF




THIS IS NOT EASY!!



Army Test and Evaluation Command

# NIE Evaluation roles

**ATEC dotMlpf**
- Focused on ability of materiel to meet user mission requirements
- Evaluate materiel performance criteria
- Assess materiel capability to meet and sustain operations during mission execution
- Evaluate Materiel effectiveness, suitability and survivability
- Provide Evaluation to Materiel Decision Authority

ATEC

BMC

DOTMLPF

DOTmLPF

TRADOC's DOTLPF analysis should determine capability gaps which drive "M" solutions

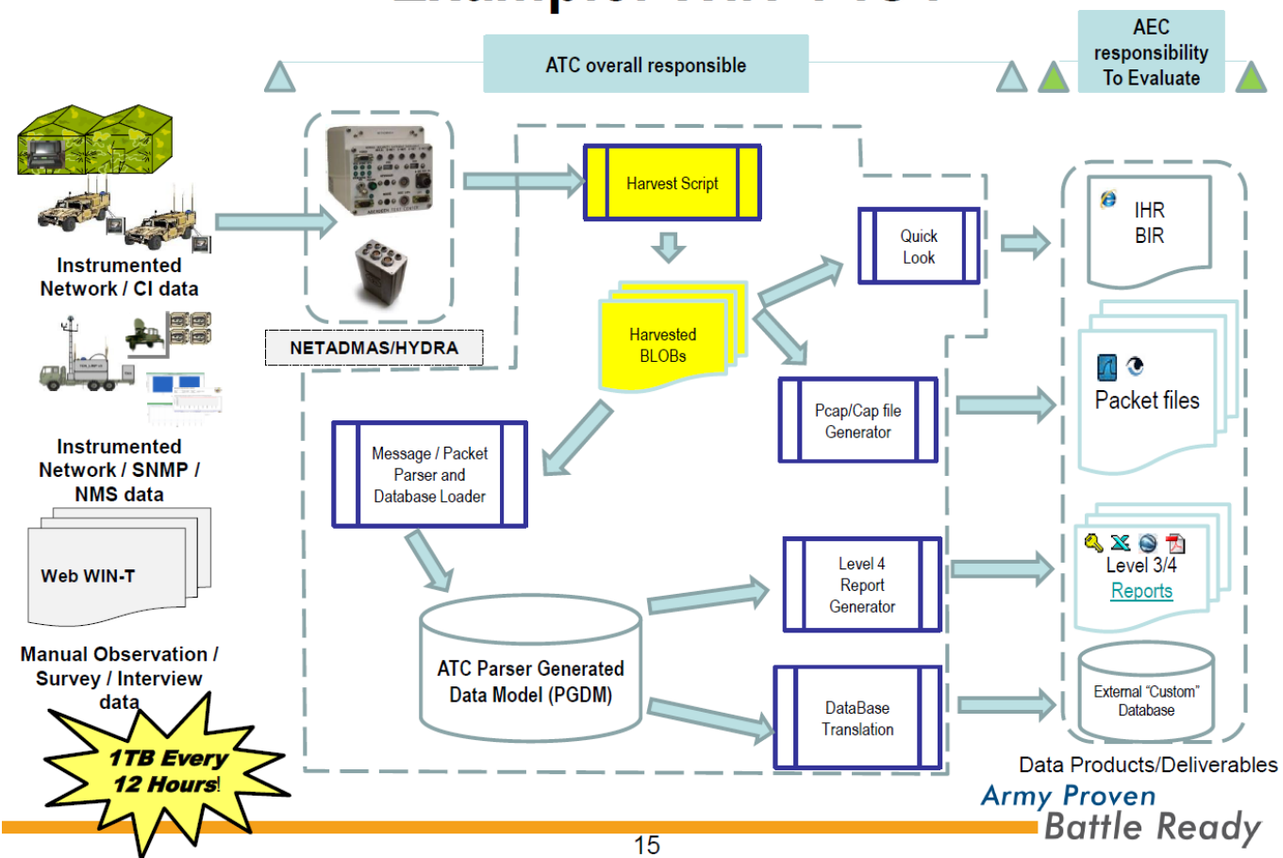
**BMC DOTmLPF**
- Focused on the ability to execute and sustain operations once deployed
- Establish criteria for mission success
- Assess mission success and identify Gaps and areas for improvement.
- Identify changes or capability gaps that can not be readily corrected (Analysis of Alternatives)
- Initiate changes as appropriate

# Products From NIE





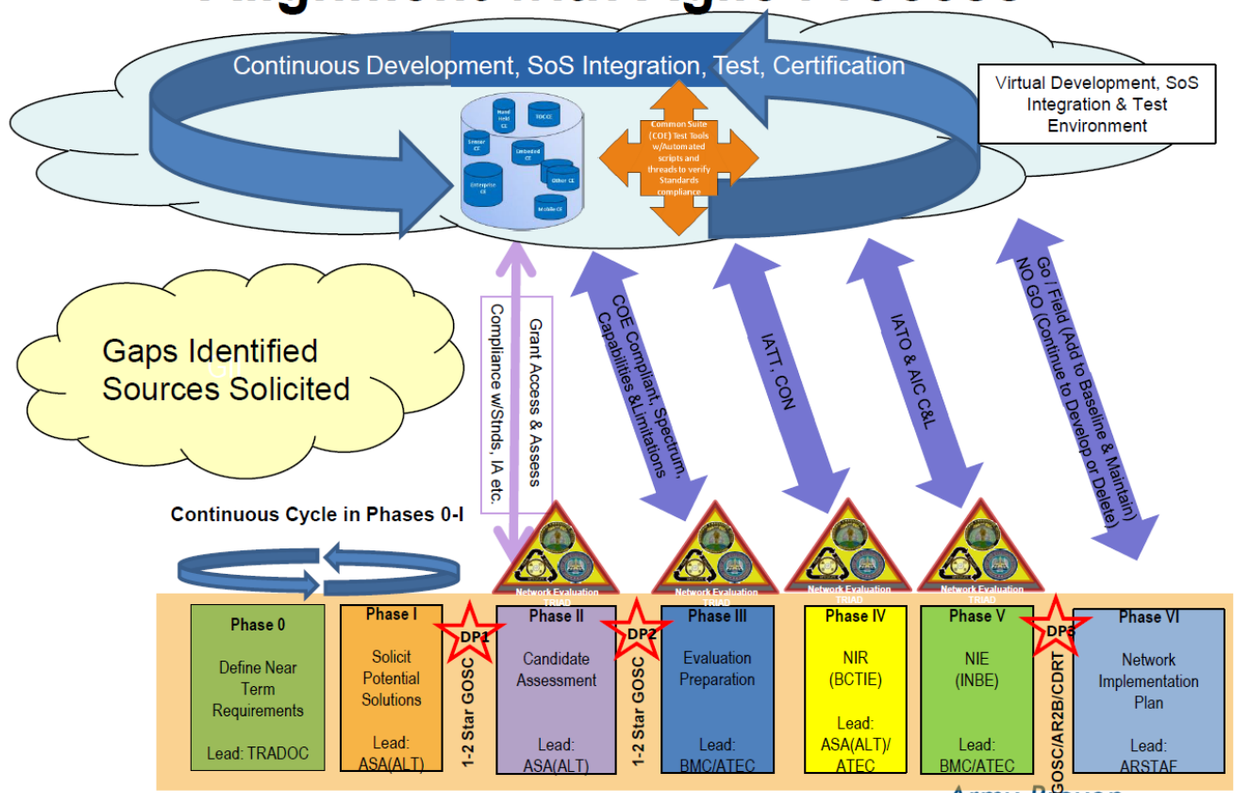

# Example: WIN-T IOT







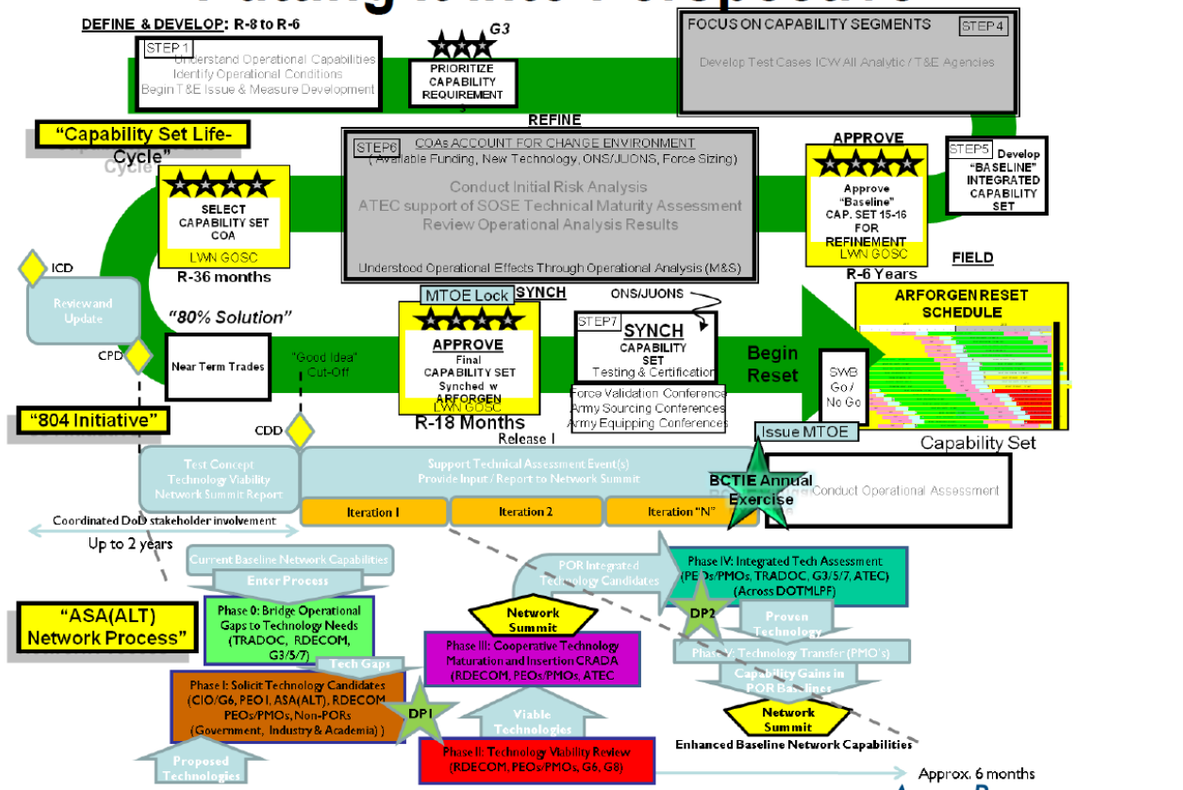

# Alignment with Agile Process

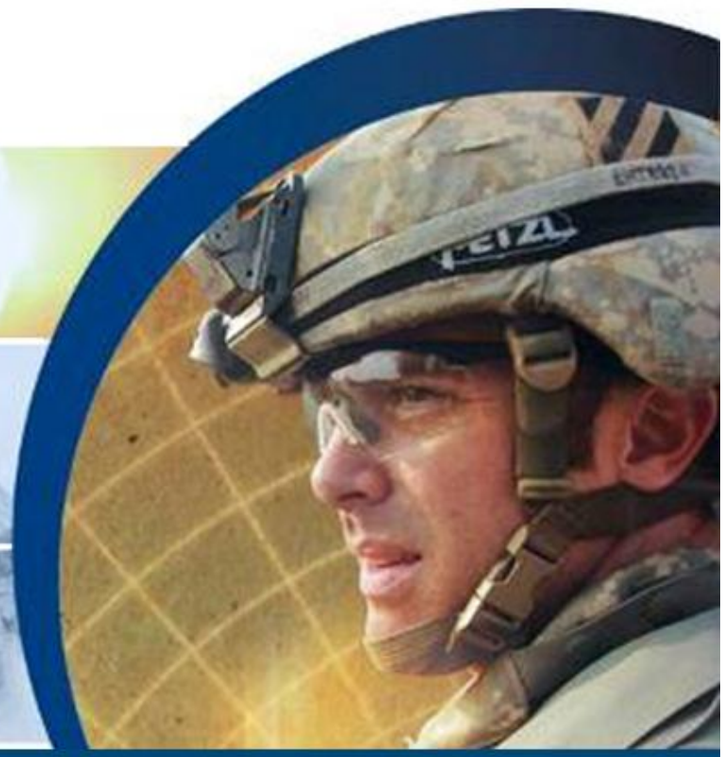







# Putting It Into Perspective





# WIN-T IOT

US Army Aberdeen Test Center

26 January 2012

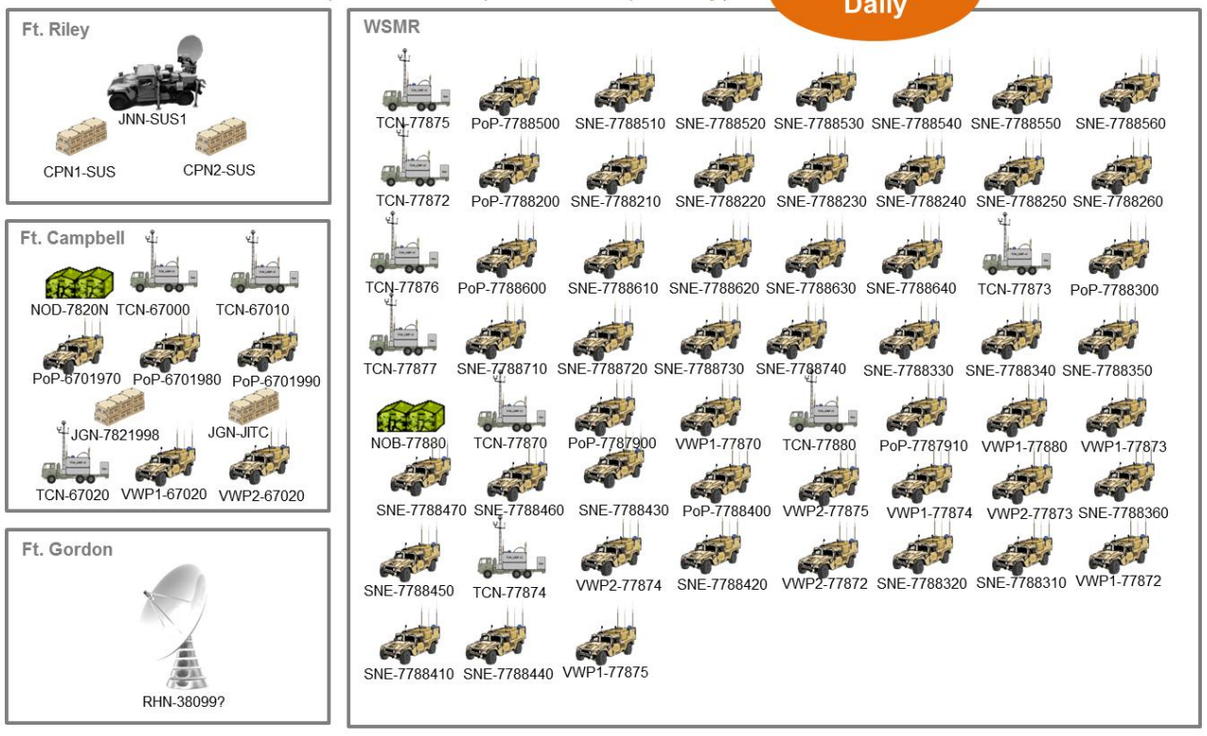
Army Proven
Battle Ready

# WIN-T NIE 12.2

75 Instrumented Platforms

~1 TB per harvest (2 harvests per day)

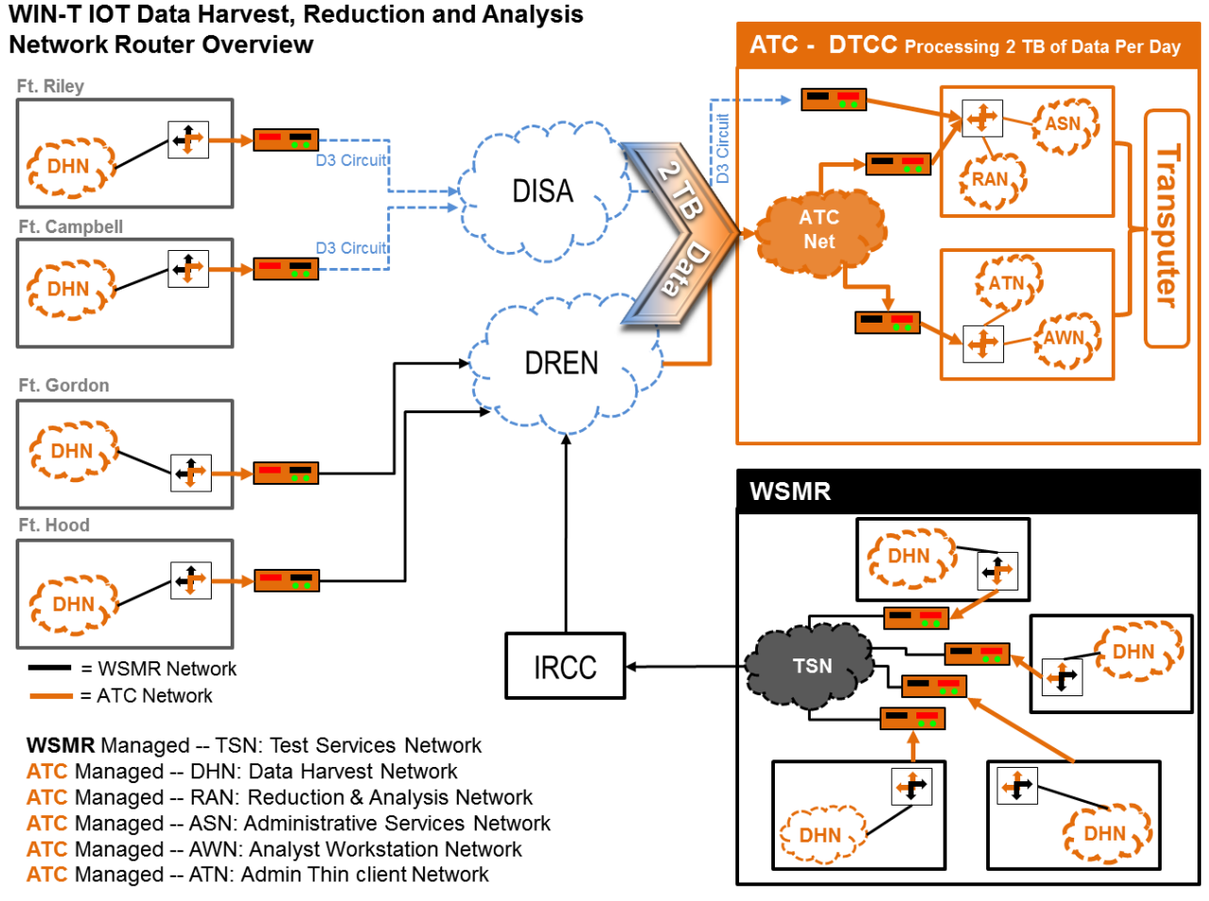
**2 TB Data Daily**




Army Proven Battle Ready

US Army Aberdeen Test Center

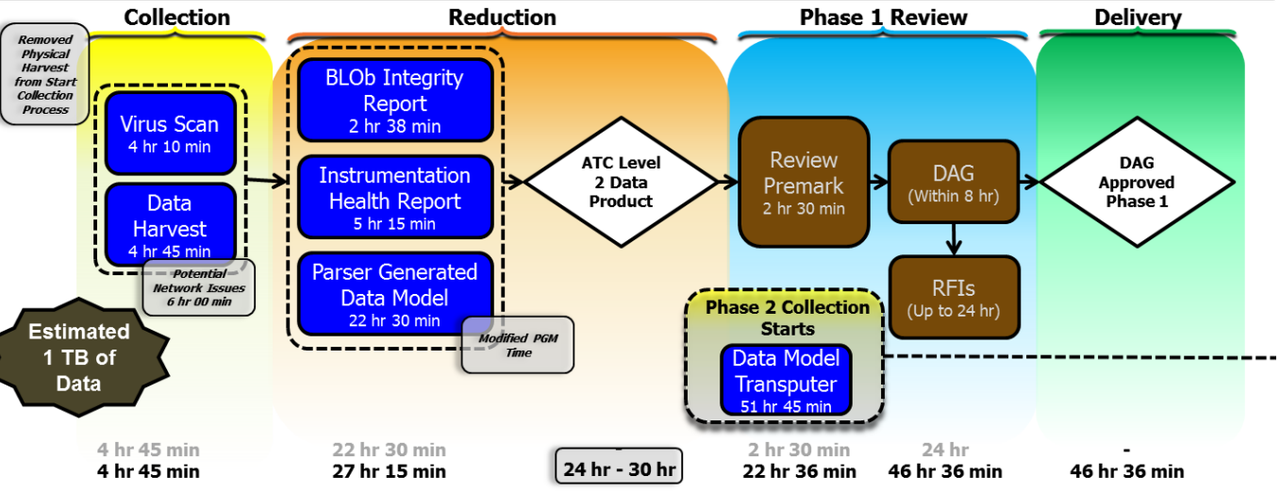
## WIN-T IOT Data Harvest, Reduction and Analysis Network Router Overview



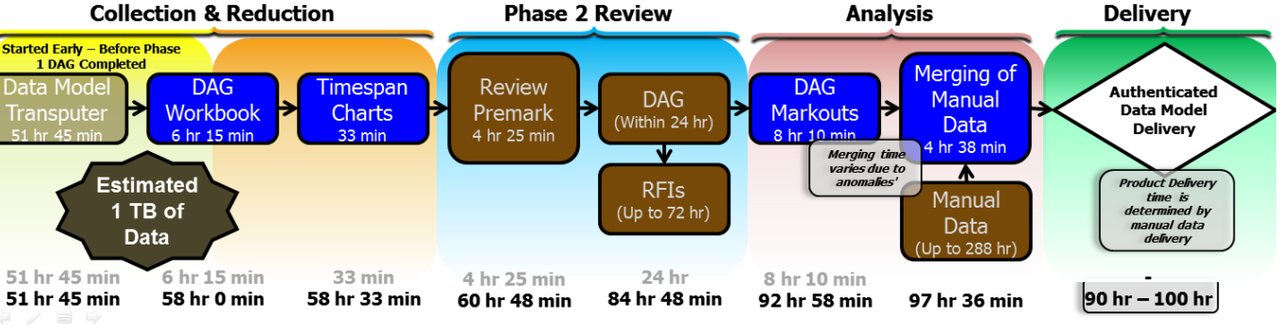

**WSMR** Managed -- TSN: Test Services Network
**ATC** Managed -- DHN: Data Harvest Network
**ATC** Managed -- RAN: Reduction & Analysis Network
**ATC** Managed -- ASN: Administrative Services Network
**ATC** Managed -- AWN: Analyst Workstation Network
**ATC** Managed -- ATN: Admin Thin client Network

Technical Processing | Non Technical / Variable | Milestones

## ATC New IOT Timeline Phase 1 – 24 hrs




## ATC's New ICE Timeline Phase 2 – 72 hrs




## Challenges / Opportunities:

- Reduce the data reduction timelines
- Validate WIN-T models produced by ARL
- Facilitate Data mining activities

# Network Integration Evaluation
# &
# Test and Evaluation

*The TRIAD:*

*Brigade Modernization Command*

*ASA(ALT) System of Systems Integration*

*Army Test and Evaluation Command*

# The Agile Capabilities Process
## A New Way of Doing Business

| TRADITIONAL APPROACH | | AGILE PROCESS |
|---|---|---|
| *5 + Years to Develop Concepts* | **CONCEPTS** | *Complete*<br>*2 Years* |
| *Not Adaptive or Flexible*<br>*Annual Process* | **GAPS** | *Complete*<br>*Warfighter Involved in Gap Analysis*<br>*Portfolio Reviews*<br>*PEO-I/ATEC/BMC = TRIAD*<br>*Focus on the Network - #1 Priority* |
| *Old/Too Narrow*<br>*Doesn't Change w/Technology or Operating Environment* | **REQUIREMENTS** | |
| *Slow, Deliberate and Expensive*<br>*Iterative and Too Many Regulations* | **DEVELOPMENT** | *In Progress*<br>*Buy Fewer More Often*<br>*Lab Efficiencies Improving*<br>*Evaluate Differently*<br>*More Alternatives Available*<br>*More Winners / Stay in the Game*<br>*PEO-I/OTC Robust Presence at Bliss/WSMR* |
| *Piecemeal Evaluations*<br>*Sequential / Not Integrated*<br>*Evaluations Did Not Reflect OE* | **EVALUATIONS** | |
| *No Technology and Alternatives*<br>*Many Losers With the Process*<br>*Time Intensive and Bureaucratic* | **ACQUISITION** | *Initiating Movement*<br>*Acquisition/Test Reform*<br>*OTC/CTSF moves*<br>*Fielding Occurs IAW Priority* |
| *Buy for the Entire Army* | **FIELD** | |



# The Agile Life Cycle

**Continuous Cycle in Phases 0-I**

**6 Months**

| Phase 0 | Phase I | DP1 | Phase II | DP2 | Phase III | Phase IV | Phase V | DP3 | Phase VI |
|---|---|---|---|---|---|---|---|---|---|
| Define Near Term Requirements<br>Lead: TRADOC | Solicit Potential Solutions<br>Lead: ASA(ALT) | 1-2 Star GOSC | Candidate Assessment<br>Lead: ASA(ALT) | 1-2 Star GOSC | Evaluation Preparation<br>Lead: BMC/ATEC | Integration Rehearsal<br>Lead: ASA(ALT)/ ATEC | Integration Evaluation<br>Lead: BMC/ATEC | GOSC/AR2B/CDR T | Network Implementation Plan<br>Lead: ARSTAF |
| • Identify requirements / gaps<br>• Prioritize List<br>• Develop initial objectives<br>• Consider feasibility<br>• Develop Assessment Criteria | • Stakeholder participation/ buy-in<br>• Obtain funding and support<br>• Initial requirements objectives<br>• Initial architecture objectives<br>• Viable candidate list | | • List of solutions that meet gaps<br>• Collaborative development<br>• Execute evaluations<br>• Validation testing<br>• Legal and contracting IA, safety, interoperability, Spectrum, Arch compliance | | • Finalize test plans (training, material, combat)<br>• NET/NEF Plan<br>• Vulnerability assessment - ARCYBER<br>• DOTMLPF collection plan<br>• Assessment report for DP2/GOSC<br>• SoS Interoperability | • DA Directives<br>• Validate Players<br>• Finalize Assessment Plan<br>• Collection / Instrumentation Plan<br>• Capabilities / Limitations List<br>• Certs and Accreditation<br>• Execute Event | • Safety Release<br>• Integrate Systems<br>• Trained and Ready Unit<br>• Approved T&E Plans<br>• OTRR/ERR<br>• Updated IRL<br>• Joint Certification/ | • Determine New Network Baseline<br>• Prioritize and Implement Systems<br>• Determine CS<br>• IOTE = FUE<br>• Determine BOI<br>• Determine resourcing |

**DP 1** - Viable Candidate List
**DP 2** - Candidates Selected for Evaluation
**DP 3** - Baseline Insertion

**TRIAD (ATEC, SOSI, BMC) Approach with Designated Leads by Phase**



# Evaluation Model
# NIE 11.2

| Q2 | | | Q3 | | | Q4 | | | Q1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | June | Jul | Aug | Sep | Oct | Nov | Dec |
| TRAIN / READY | | | NIE 12.2 AVAILABLE | | | RESET / TRAIN / READY | | | NIE 13.1 AVAILABLE | | RESET |

### Soldier Training & Leader Development

- *New Equipment Fielding (NEF)*
- *New Equipment Training (NET)*
- *Leader Development Solutions*

### Rehearsals

- *Network Integration Rehearsal (NIR)*
- *COMMEX*
- *LOGPAC Rehearsal*
- *PCC's & PCI's*

### Equipment Evaluation

*Integration with current equipment*
*Training plans for equipment*
*Performance in a tactical scenario*

### Soldier Feedback

*Physical – Weight, size, cabling*
*Interaction – Menus, Navigation, Improvements*
*Failure modes – How and where does it break*

### Leader Feedback

*Tactical Implementation – Did it perform*
*Meets Needs – Did it work as intended or planned*
*Improvements – Making equipment better*

14 APR — 30 MAY — 8 JUN — 22 JUL

***DOTLMPF Evaluation conducted throughout the 3 month assessment window***

# Phase VI - Inputs, Outcomes/Outputs & Reports

**Inputs**

*Integrated data collection and analysis effort*

- *Unit Commanders Operational Benefit assessment*
- *System contribution to Warfighter function*
- *Instrumented data collection and analysis*
- *DOTmLPF data*
- *CoE SME observations*
- *AAR & lessons learned*
- *O/C Observation*
- *Soldier surveys*

**Outputs**

*TRIAD Consolidated Post-NIE Report*

- *Executive Summary recommending System continuance*
- *Integrated Network Assessment Report*
- *49 x system DOTmLPF assessments*
- *49 x SUE ATEC Capability & Limitations Report/Forward Operational Assessments*
- *1 x SUT ATEC OTA Assessment Report (OAR) for Rifleman's Radio Initial Operations Test and Evaluation*
- *ATEC Instrumented Certification: WINT-INC2*

**Exsum**

Network Annex A

ATEC Network Append. 1

SUT/SUE 49-Annexs

ATEC SUE 49-Appends



# Lessons Learned

## *Brigade Lessons Applied Toward NIE 12.1 & 12.2:*

- *Required More robust Training Support Packages (TSPs) during New Equipment Training (NET) and Sustainment Training*
- *Leader training needed to be more intensive based on equipment. Soldiers understood how to operate but leaders did not have employment knowledge.*
- *Requested Systems Under Test (SUTs) and Systems Under Evaluation (SUEs) to arrive at Ft. Bliss, TX integration-ready. Utilize Aberdeen Proving Ground as test grounds*
- *Network integration between the terrestrial ground network and satellite systems needed to be completed prior to issuing equipment*



# NIE 11.2 & 12.1 Lessons Learned

- *A single consolidated DOTMLPF report provided 25-days after the NIE, to assist HQDA with resourcing and budgetary decisions.*
- *Early link-up between Industry partners, Program Managers, and TRADOC stakeholders facilitates successful progression within the Agile Process.*
- *Earlier deliberate candidate solution evaluation lead by HQDA G/3/5/7 LB to ensure NIE entrance criteria is met.*
- *A more deliberate, standardized process for entry into NIE, from the Tech Call to GOV and Sources Sought to Industry, to the evaluation process chaired by ASAALT, MC COE, TRADOC, and ATEC.*
- *Industry participated in NIE 12.1 for the first time. Continue to improve the system to inform industry on SUE observations & sharing of technical data.*



# Future Test & Evaluation Requirements:

- *Portable range extension from fixed facility high capacity fiber optic LANs to facilitate data collection/transfer for operational tests*
- *Over the air data collection ("silent monitoring") capability of IP based radio and cellular networks*
- *Built in instrumentation or data logging feature on all future DOD procurements*
- *Distributed test network connectivity for agile process*
- *Metrics for assessing Common Operational Environment (Capability Set 13 is COE 1.0)*
- *NETOPS tools that provide both network monitoring and data collection without extensive network "overhead"*

# Best Practices Model for Systems-of-Systems Systems Engineering and Test & Evaluation

## January 26, 2012

Rob Heilman
Test Resource Management Center

26 January 2012

ITEA White Sands Chapter
The T&E of System-of-Systems Conference

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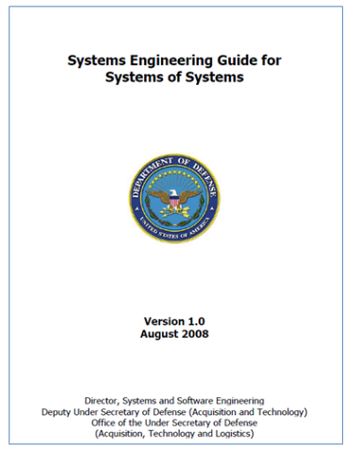
571-372-2720



# SoS Basics

- **A growing number of military capabilities are achieved through a systems of systems (SoS) approach**
  - **Trend is likely to continue for foreseeable future; concentrate on optimization of the mission**

- SoS differ from traditional systems in ways that require tailoring of systems engineering and T&E processes
  - SoS do not have 'requirements' per se;
    - Requirements are defined and funded at individual system levels
    - Acquisition (including SE and T&E) of systems is typically independent from SoS
  - SoS have capability objectives or goals
    - Foundation for specific requirements drive changes to constituent systems in increments of SoS evolution






# Back to the Question of Why SoS T&E

- It is the only way to test…
  - End-to-End Mission Threads
  - Mission Effectiveness
  - Combat Capability
  - Operational Risk
  - Unintended Consequences
  - 2nd & 3rd Order Effects



# Summary and Next Steps

- Key elements of the approach to SoS SE and T&E
  - Addresses the key challenges facing T&E in an SoS environment – complexity, system independence and asynchronous development
  - Integrates T&E with SE throughout the evolution of an SoS based on the SoS 'wave model' – T&E contributes to all steps in the evolution
  - Focuses T&E on risks to systems and SoS – recognizing full end to end testing with each system change is intractable
- Presentation is the product of the 2011 joint task of the NDIA SoS SE and T&E committees
  - Represents initial product in this area
  - Next steps
    - Finalizing model and sharing it across the community
    - Planning for next steps in model development

# Comparing Systems and SoS

| | System | Acknowledged System of Systems |
|---|---|---|
| **Management & Oversight** | | |
| **Stakeholder Involvement** | Clearer set of stakeholders | Two levels of stakeholders with mixed possibly competing interests |
| **Governance** | Aligned PM and funding | Added levels of complexity due to management and funding for both SoS and systems; SoS does not have control over over all constituent systems |
| **Operational Environment** | | |
| **Operational Focus** | Designed and developed to meet operational objectives | Called upon to meet operational objectives using systems whose objectives may or may not align with the SoS system's objectives |
| **Implementation** | | |
| **Acquisition** | Aligned to established acquisition processes | Cross multiple system lifecycles across acquisition programs, involving legacy systems, developmental systems, and technology insertion; Capability objectives but may not have formal requirements |
| **Test & Evaluation** | Test and evaluation the system is possible | Testing more challenging due systems' asynchronous life cycles and given the complexity of all the moving parts |
| **Engineering & Design Considerations** | | |
| **Boundaries & Interfaces** | Focuses on boundaries and interfaces | Focus on identifying systems contributing to SoS objectives and enabling the flow of data, control and functionality across the SoS while balancing needs of the systems |
| **Performance & Behavior** | Performance of the system to meet performance objectives | Performance across the SoS that satisfies SoS user capability needs while balancing needs of the systems |

## T&E Implications

Validation criteria more difficult to establish

Cannot explicitly impose SoS conditions on system T&E

System level operational objectives may not have clear analog in SoS conditions that need T&E

Depends on constituent system test of SoS requirements as well as SoS level

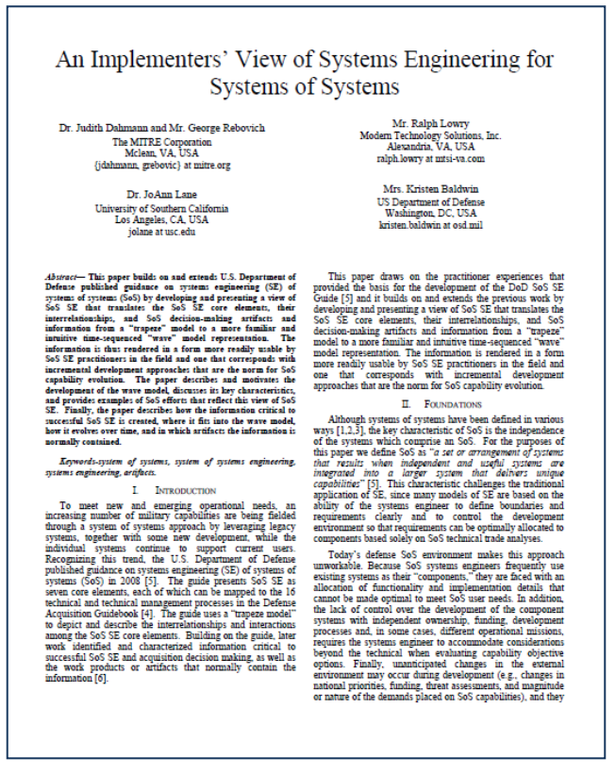
Difficult to bring multiple systems together for T&E in synchrony with capability evolution

Additional test points needed to confirm behavior

Increased subjectivity in assessing behavior, given challenges of system alignment

Reference: US DoD Guide for Systems Engineering of Systems of Systems

# Wave Model: Framework for Model



An Implementers' View of Systems Engineering for Systems of Systems

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*Abstract*— This paper builds on and extends U.S. Department of Defense published guidance on systems engineering (SE) of systems of systems (SoS) by developing and presenting a view of SoS SE that translates the SoS SE core elements, their interrelationships, and SoS decision-making artifacts and information from a "trapeze" model to a more familiar and intuitive time-sequenced "wave" model representation. The information is thus rendered in a form more readily usable by SoS SE practitioners in the field and one that corresponds with incremental development approaches that are the norm for SoS capability evolution. The paper describes and motivates the development of the wave model, discusses its key characteristics, and provides examples of SoS efforts that reflect this view of SoS SE. Finally, the paper describes how the information critical to successful SoS SE is created, where it fits into the wave model, how it evolves over time, and in which artifacts the information is normally contained.

*Keywords-system of systems, system of systems engineering, systems engineering, artifacts.*

I. Introduction

To meet new and emerging operational needs, an increasing number of military capabilities are being fielded through a system of systems approach by leveraging legacy systems, together with some new development, while the individual systems continue to support current users. Recognizing this trend, the U.S. Department of Defense published guidance on systems engineering (SE) of systems of systems (SoS) in 2008 [5]. The guide presents SoS SE as seven core elements, each of which can be mapped to the 16 technical and technical management processes in the Defense Acquisition Guidebook [4]. The guide uses a "trapeze model" to depict and describe the interrelationships and interactions among the SoS SE core elements. Building on the guide, later work identified and characterized information critical to successful SoS SE and acquisition decision making, as well as the work products or artifacts that normally contain the information [6].

This paper draws on the practitioner experiences that provided the basis for the development of the DoD SoS SE Guide [5] and it builds on and extends the previous work by developing and presenting a view of SoS SE that translates the SoS SE core elements, their interrelationships, and SoS decision-making artifacts and information from a "trapeze" model to a more familiar and intuitive time-sequenced "wave" model representation. The information is rendered in a form more readily usable by SoS SE practitioners in the field and one that corresponds with incremental development approaches that are the norm for SoS capability evolution.

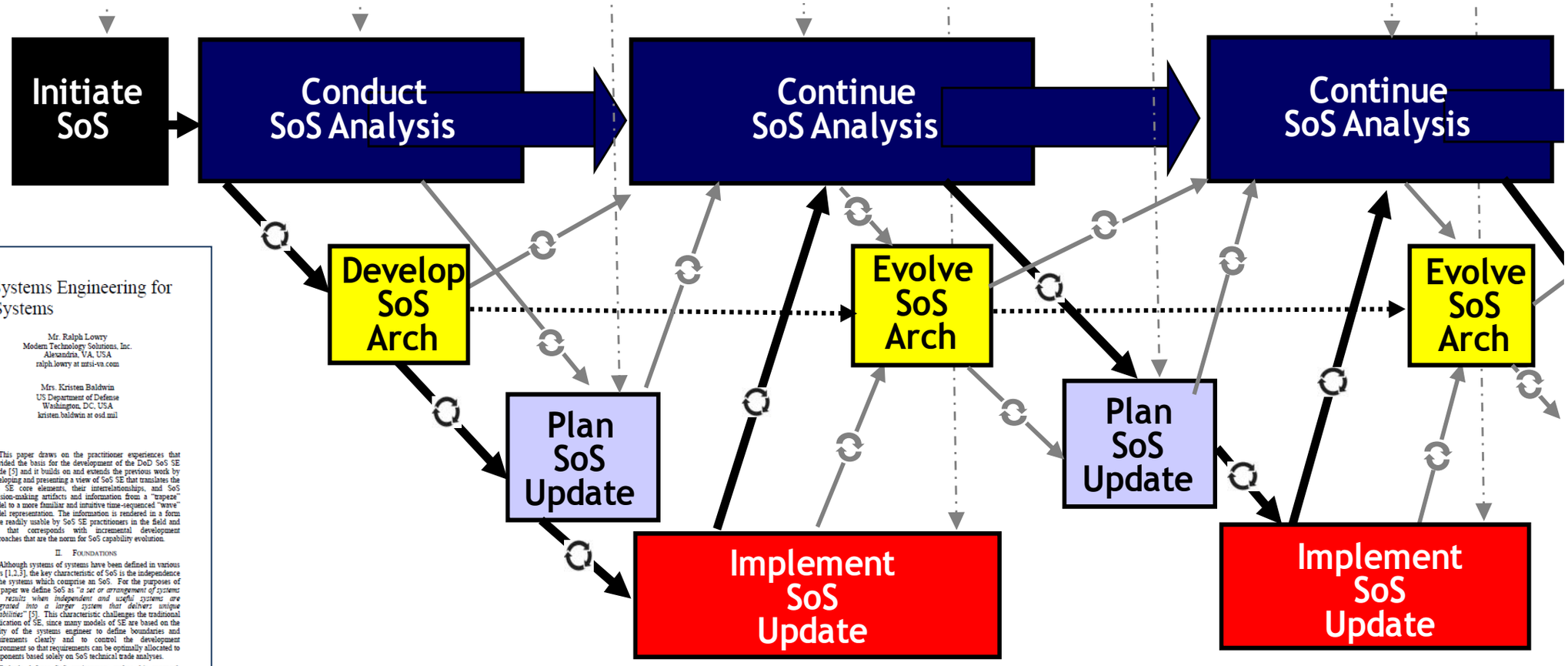
II. Foundations

Although systems of systems have been defined in various ways [1,2,3], the key characteristic of SoS is the independence of the systems which comprise an SoS. For the purposes of this paper we define SoS as *"a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities"* [5]. This characteristic challenges the traditional application of SE, since many models of SE are based on the ability of the systems engineer to define boundaries and requirements clearly and to control the development environment so that requirements can be optimally allocated to components based solely on SoS technical trade analyses.

Today's defense SoS environment makes this approach unworkable. Because SoS systems engineers frequently use existing systems as their "components," they are faced with an allocation of functionality and implementation details that cannot be made optimal to meet SoS user needs. In addition, the lack of control over the development of the component systems with independent ownership, funding, development processes and, in some cases, different operational missions, requires the systems engineer to accommodate considerations beyond the technical when evaluating capability objective options. Finally, unanticipated changes in the external environment may occur during development (e.g., changes in national priorities, funding, threat assessments, and magnitude or nature of the demands placed on SoS capabilities), and they

**Presented at IEEE Systems Conference April 2011 [1]**

[1] "An Implementers View of Systems of Systems" Dahmann, Baldwin, Rebovich, Lane and Lowry

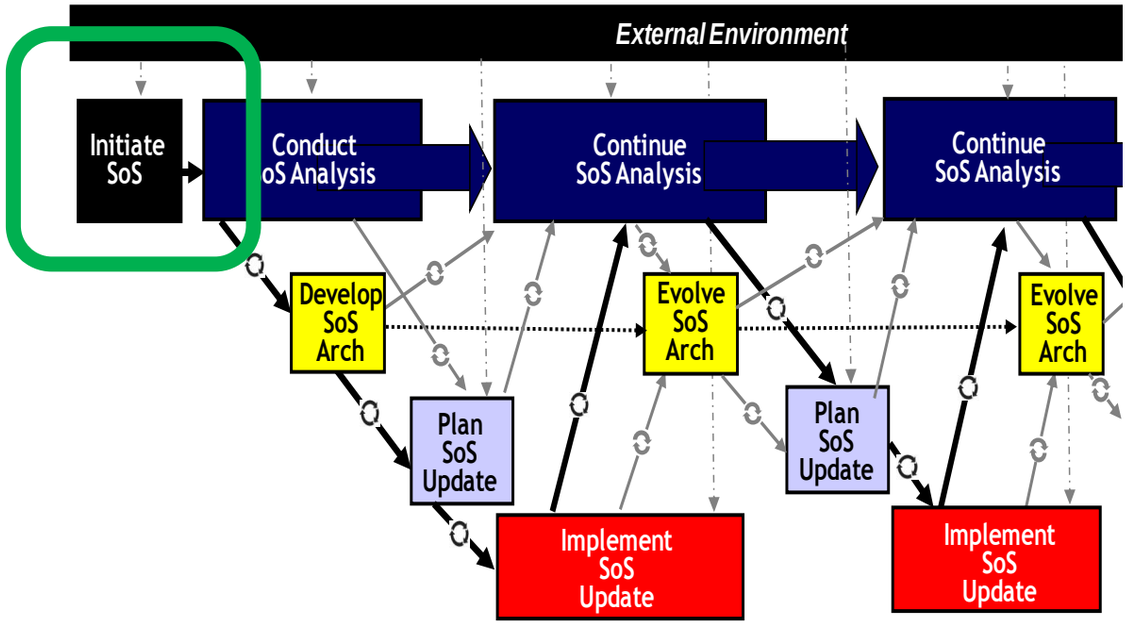



**An implementer's view of SoS SE**

- More familiar and intuitive time-sequenced "wave" model representation
- Information is thus rendered in a form more readily usable by SoS SE practitioners in the field
- Representation that corresponds with incremental development approaches that are the norm for SoS capability evolution

Concept of Wave Planning was developed by Dr. David Dombkins See "Complex Project Management" Booksurge Publishing, South Carolina: 2007.

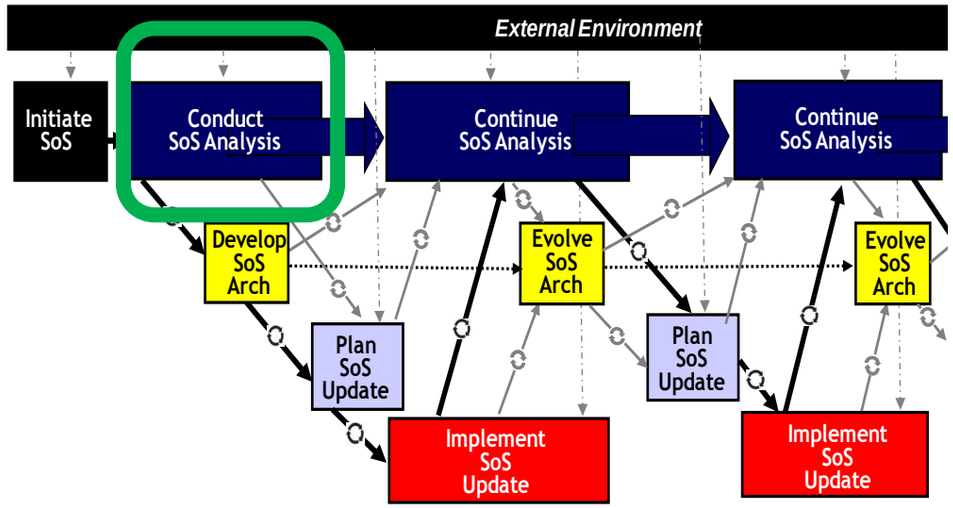
# Approach Assumes "Initiation" of an Acknowledged SoS




- Decision has been made to establish an SoS SE organization
- At the initiation of an SoS, the information typically available includes initial or first order
  - Statement of top-level objectives for the SoS (SoS Capability Objectives)
  - Description of how systems in the SoS will be operationally employed (SoS CONOPS)
  - Programmatic and technical information about systems that affect SoS capability objectives (Systems Information)
  - Risks are identified when an SoS is launched and mitigation actions are tracked and updated throughout each cycle, along with new risks (Risks and Mitigations)

# SoS SE: Conduct SoS Analysis

**Provides analysis of the 'as is' and basis for SoS evolution**



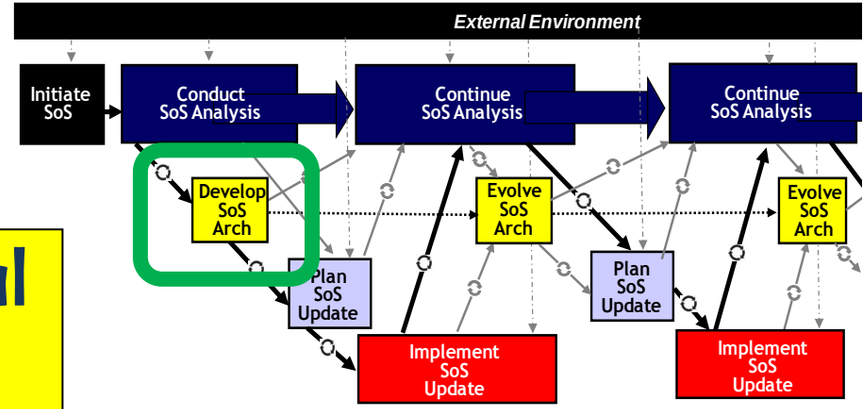

- **SE Activities:**
  - Understand CONOPS, operational context, mission threads, conditions, players, performance objectives
  - Mission threads decomposed to tasks and systems to understand end-to-end capability objectives and current performance (functional and current system baseline)
  - Develop a functional architecture for the SoS
  - Develop SE Planning elements, SoS Master Plan, Agreements

- **T&E Activities:**
  - Understand T&E of current constituent systems for systematic development and analysis of data to identify where more data needed (and testing may be required) are identified
  - Ensure CONOPS, Functional and System Baseline definitions support testable elements

**T&E foundations are established in SoS analysis which draws on T&E of constituent systems**

# SoS SE: Develop SoS Architecture

**Develops and evolves the persistent technical framework for addressing SoS evolution**




- **SE Activities:**

  – Identify and evaluate alternative approaches to organizing and augmenting systems to meet SoS need

  – Define the way systems work together to meet end-to-end capability objectives including data flow and communications (SoS Architecture)

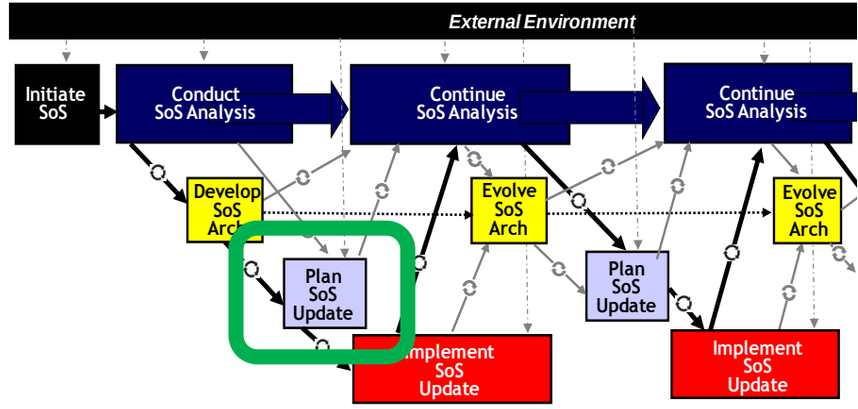
- **T&E Activities:**

  – System and or previous SoS T&E is key to identification and analysis of alternative architectures

**SoS SE and SoS T&E share key common elements;**
**It can be difficult to tell where SoS SE stops and SoS T&E begins**

# SoS SE: Plan SoS Update

**Evaluates the SoS priorities, options and backlogs to define the plan for the next SoS upgrade cycle.**

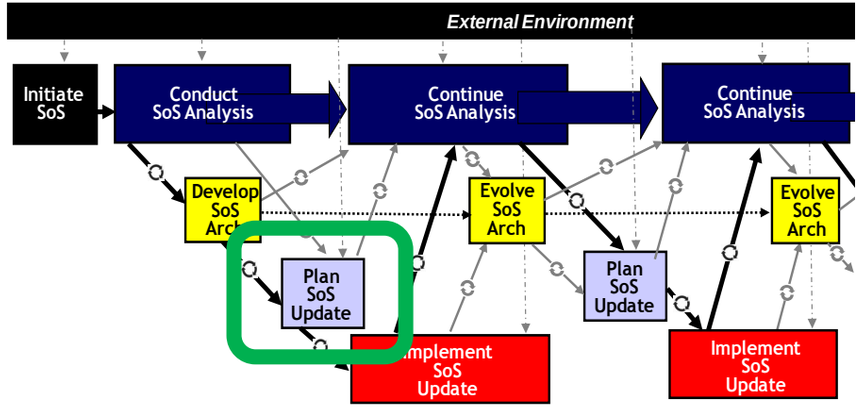



- **SE Activities:**
  - Identify needs to be addressed in this Wave (Allocated Baseline)
  - Plans for System and SoS Development (Integrated Master Schedule)
  - Identify risks and mitigations (Risks and Mitigations)

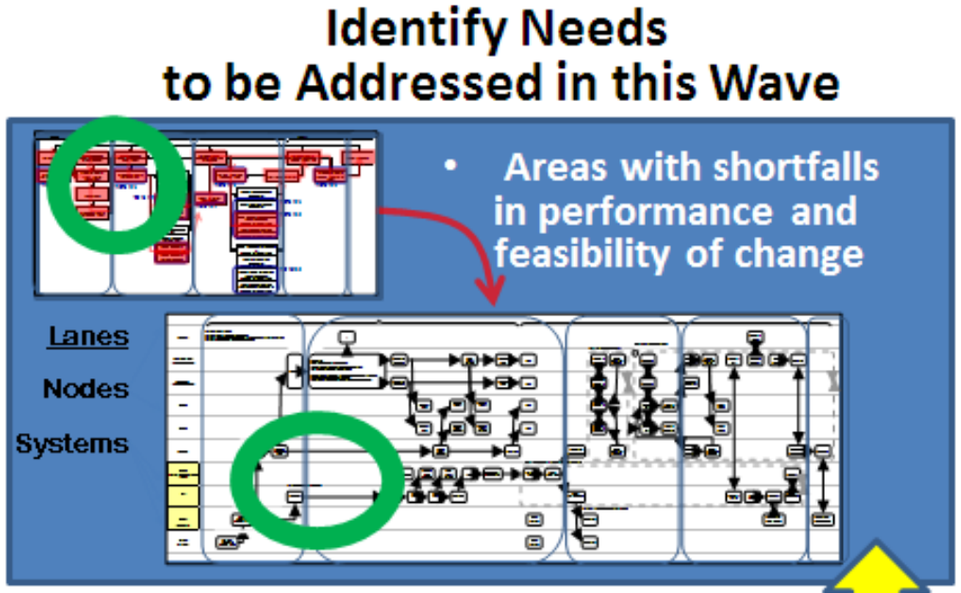
- **T&E Activities:**
  - Analyze allocated baseline and risks to identify the areas to be addressed by T&E (Integration and Test Plan)
    - Define what data is needed and how can this be obtained? (System or SoS Test)
    - Define what testing tools and environment are needed to address the specific changes? (Test Drivers for System T&E, SoS LVC T&E Environment)

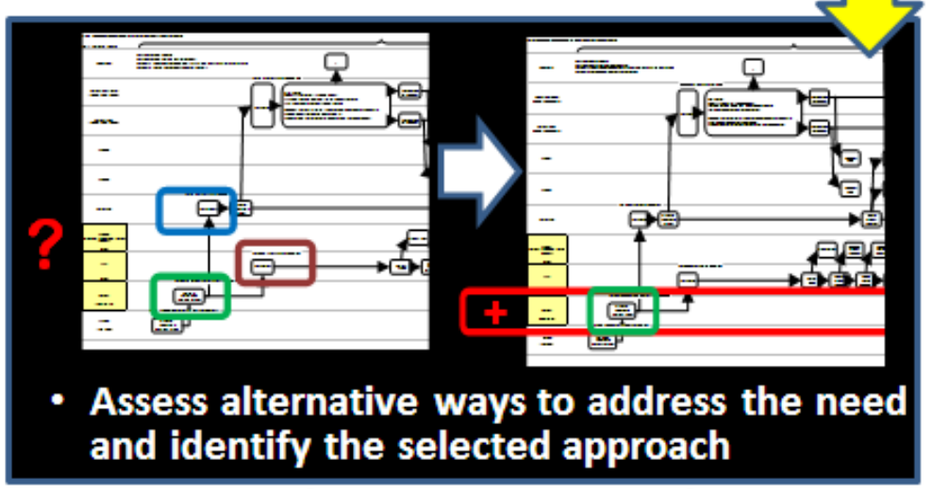
**SoS SE and T&E activities diverge at this step.**
**SoS SE focus on defining SoS Allocated Baseline & Risks.**
**SoS T&E focus on development of Integration and Test Plan.**

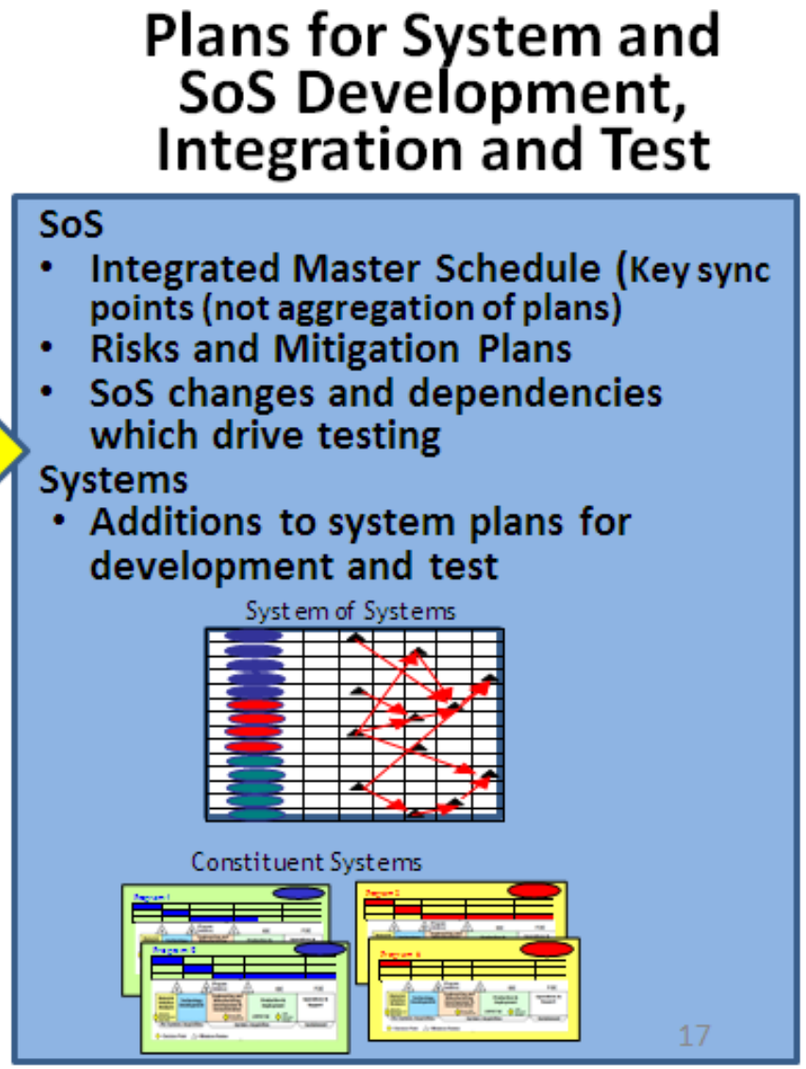
# SoS SE: Plan SoS Update



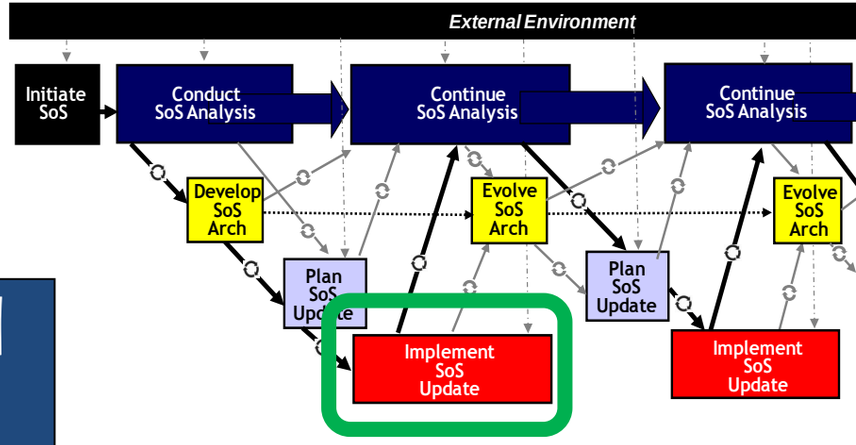

## *Illustrative Products & Activities*



# SoS SE: Implement SoS Update



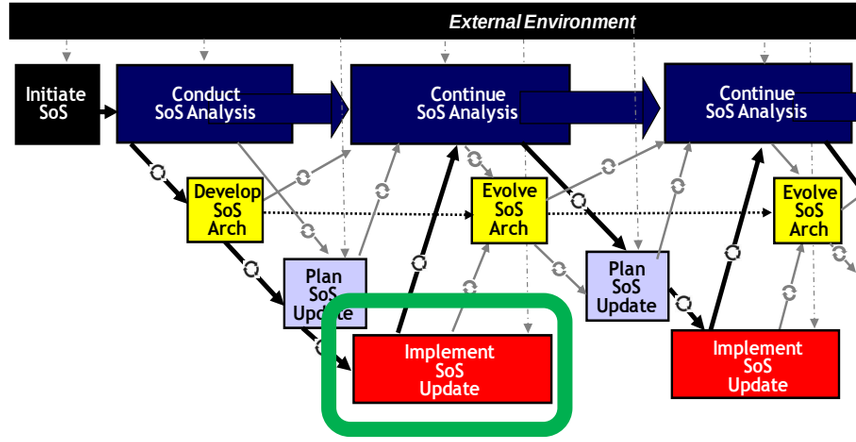

**Monitors implementations at the system level and plans and conducts SoS level testing, resulting in a new SoS product baseline**

- **SE Activities:**
  - Monitors system and SoS development, integration, and testing (New SoS baseline)
  - Informs users of new baseline capabilities

- **T&E Activities:**
  - T&E is key part of implementation
  - Collect System T&E data (System Test Reports)
  - Conduct required SoS T&E, data analysis and reporting (SoS Test Report)
  - Provide recommendation for regression testing for next wave increment

**SoS SE controls baseline release to operational users.**
**SoS T&E conducts and reports on test.**

# SoS SE: Implement SoS Update

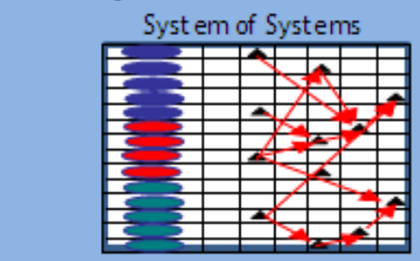


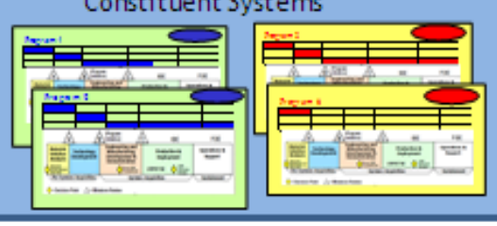

## *Illustrative Products & Activities*

### Monitor System and SoS Development, Integration and Test

SoS
- Integrated Master Schedule (Key sync points, not aggregation of plans)
- Risks and Mitigation Plans
- SoS changes and dependencies which drive testing

Systems
- Additions to system plans for development and test

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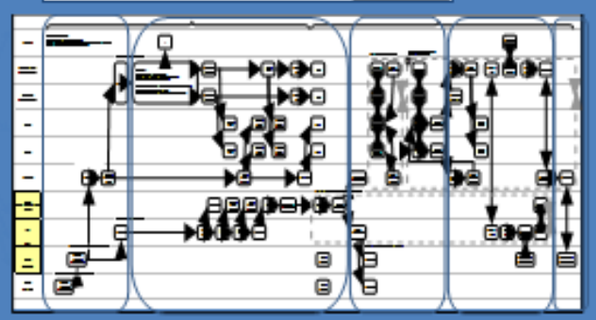
### Review Progress And Inform Users and SE Process

- Collect and assess data from system and SoS development technical reviews and tests
- Update product baseline, architecture, performance assessments, and requirements space
- Provide input into 'Continue SoS Analysis'



# Introduction to
# Integrity Assessment
## of Arbitrarily Large, Complex, Heterogeneous, Changing Systems

Antonio Pizzarello, Ph.D. Byron Davies Ph.D.
Oris Friesen, Ph.D. Jack Ring

OntoPilot LLC
Gilbert, AZ
March 10, 2012

## Problematic Situation

- We build a system for what we want it do on behalf of its stakeholders, particularly for the effect it can have on its context.
- We verify, validate, test & evaluate the system we are building to foresee what it will do regardless of what we and others want it to do.
- A system, whether built, integrated or a mash-up can exceed the cognitive limits of its caretakers.
- As system extent, variety and ambiguity increase then V&V and T&E become intractable.
- Further, V&V and T&E can only find those faults that manifest as recognized errors.
- System Integrity Assessment is a better way of finding all faults and incompatibilities in any configuration -- quickly.



## Time to Re-Assess V&V and T&E?

- How much T&E time and budget is wasted due to systems that are not ready for T&E? (≈ 40%?)
- What is the relative benefit of detecting a faulty design early rather than in system test? (> 1,000:1?)
- After extensive T&E what is the likelihood that latent faults still exist? (≈ 1/1000 SLOC?)
- Does the scale and "mean time to change" of current large scale, complex systems and 'system of systems' make T&E cycle time and cost unacceptable?
- It is time to consider new ways of assessing whether a system is Fit for Purpose.
- Such assessments can be made, quickly, throughout a system life cycle.



## Two Key Attributes of All Systems

- Systems become evident when component mechanisms interact with system context. The evidence is called behavior or emergence and is either acceptable or not.
- These mechanisms are algorithms realized as programs or are machinery that can be described by algorithms
- Algorithms are prescriptions for changing the content of data. Data values correspond to mechanism states
- All algorithms and system thereof have two kind of properties:

# Leading Indicators

Shawn S. Smith Ph.D.
L-3 Communications

**ITEA T&E SOS Conference**
**January 26th 2011**
**El Paso, TX**



# Agenda

- Unused and underused technology remains a persistent problem in Information Technology (IT)
- Leading Indicators as defined by the International Council on Systems Engineering (INCOSE)
- Technology Models help us understand and influence technology acceptance
  - The Technology Acceptance Model (TAM)
  - Other models that may be interesting
- Summary
- Discussion



# Technology Acceptance Model (Davis, 1989)

- Two variables influence user acceptance of technology
  - Perceived Usefulness
  - Perceived Ease of Use
- Ease of Use moderates Usefulness
- Introduced in 1989; a validated and well-used (critics say overused) quantitative model
- Hundreds of studies that validate and/or extend the model
- Populations studied include students, professionals, and the military
- Technologies studied span business software, consumer electronics, communications and network protocols, and specialized systems used by police and the military
- Data collection is via straightforward survey methods
  - Automating data collection (Use data) may inform test reliability
- Data is well suited to modeling with multiple regression methods



# Summary

- INCOSE provides 18 Leading Indicators
  - Technology acceptance measures might loosely fit in the Technology Maturity Trends Leading Indicator
  - Current Leading Indicators for Human System Integration (HSI) offer only weak characterization
  - We need better tools to perform SE for Human Factor Engineering (HFE)
- The Technology Acceptance Model applied early in the SE process (as a type of Leading Indicator)
  - A starting point for Leading Indicators suitable for evaluating technology acceptance
  - A low cost, low risk, but effective method to validate user acceptance and subsequent use
  - A way to initiate new conversations with the consumer community
  - A methodology for Systems Engineers and Operations Researchers to track and evaluate how system interfaces evolve in the eyes of consumers
  - Contributes to managing IT as the commodity it is

ITEA: The T&E of System-of-Systems Conference
El Paso, Tx
24-27 January 2012

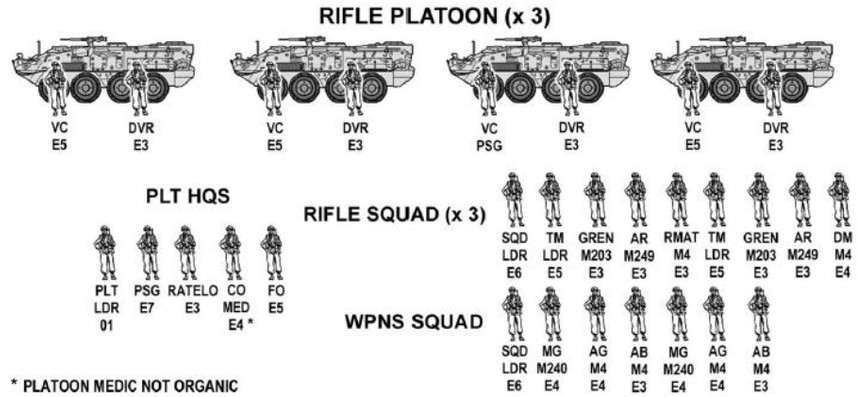
# Infantry Squad: A System of Systems

Al Sciarretta
CNS Technologies, Inc.

# Army Infantry Rifle Squad

## Part of an Army Rifle Platoon


SQD LDR = Squad Leader
TM = Team Leader
GREN = Grenadier
AR = Automatic Rifleman
RMAT = Rifleman, Anti-Armor Specialist
DM = Designated Marksman






# Test Drivers:

## Possible Future Enhancements to the Squad

- Materiel
  - Integration of the platoon/squad into:
    - Communications networks
    - Information networks (including access to organic/supporting sensors)
    - Socio-cognitive networks
  - Autonomous system support
    - ISR/lethality augmentation (e.g., small/micro-autonomous ground/air systems)
    - Load-carrying robotic vehicles
  - Enhanced lethality
    - Synchronization of organic and supporting fires
    - Ability to deliver both lethal and non-lethal effects
    - Ability to counter improvised UAVs
  - Enhanced maneuverability
    - Especially in urban environments



# Test Drivers

## Possible Future Enhancements to the Squad

- Human Dimension
  - Situational awareness (SA), decision making, and execution of decisions.
    - For example, shared SA:
      - Level 1 SA: location/status red forces
      - Level 2 SA: what are the objectives of red forces
      - Level 3 SA: what will red forces do in next 15 minutes
  - Squad design from psychological and physiological perspectives
  - Ability to deal with “stressors” as a team
  - Advanced training, planning, and rehearsal

Track 1 included a town-hall* session and a “world café” * session, both chaired by John Thomas with assistance from Regina Griego, Jack Ring, and Thomas Tenorio. Participants viewed these sessions quite positively, and several great ideas emerged for improving the practices for testing and evaluating of systems of systems and for systems engineering of T&E in this context.

Three Reports were produced:

- Steven Slater, Town Hall and World Café notes.final.docx
- Jack Ring, 120127 Readout World Café – jack ring.docx
- Thomas Tenorio, Environment & SoS (Thomas Tenorio v1.3).doc

These reports will be made available by request.

* Details on the value of town halls and world cafes can be found across the internet but a good starting point can be found at the following link: http://technologyinprevention.wikispaces.com/THM+meets+TWC

Key Current Issues

Composition:
SOSE seems to describe only the acquisition phase activity but not the in-field logistics activity. A SOS Kaizen process must be instantiated that harmonizes technology insertion with warfighter engagement modeling.

Faults:
T&E discovers only errors (the faults encountered by the test cases) not the whole set of faults. System Integrity Assessment will be more effective now that it is technologically feasible. Also, a focus on effect, capabilities and morphing (rather than requirements).

Ambiguity:
No one knows what components comprise a SOS. Even if once known the configuration changes continually unbeknownst to the users.  No process ever repeats. Re-use doesn't work. Everyone is making decisions with incomplete information.