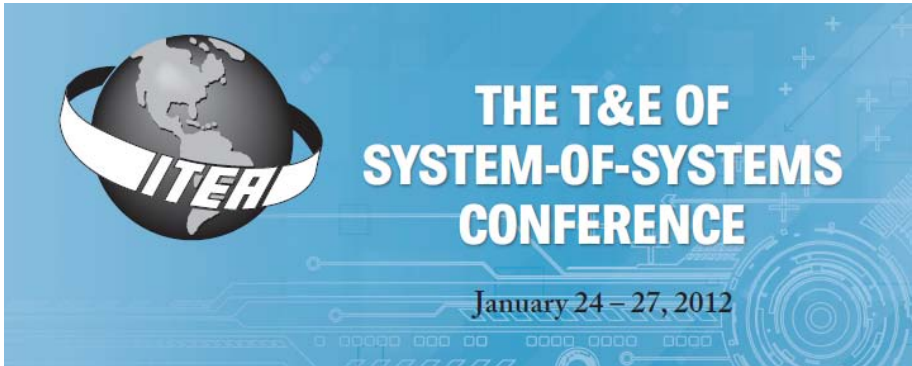
Engineering, Operations & Technology
Boeing Test & Evaluation

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

Test As You Operate Panel

Kevin Knudsen

January 25, 2012



Mr. Kevin Knudsen

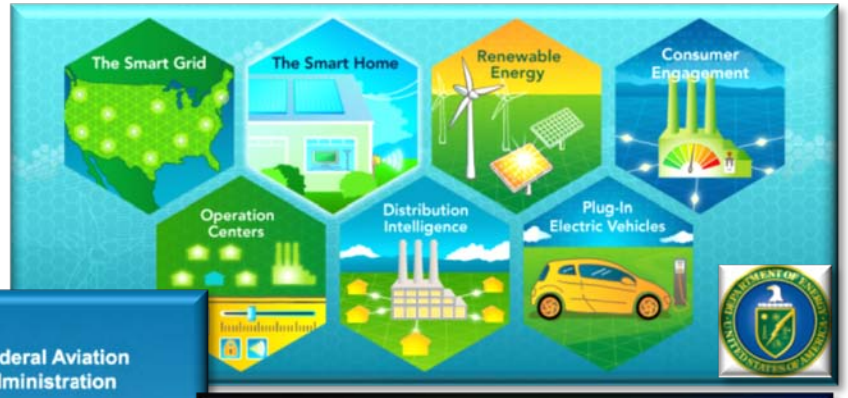
Systems/System of Systems Test Capability Leader
Boeing Test & Evaluation

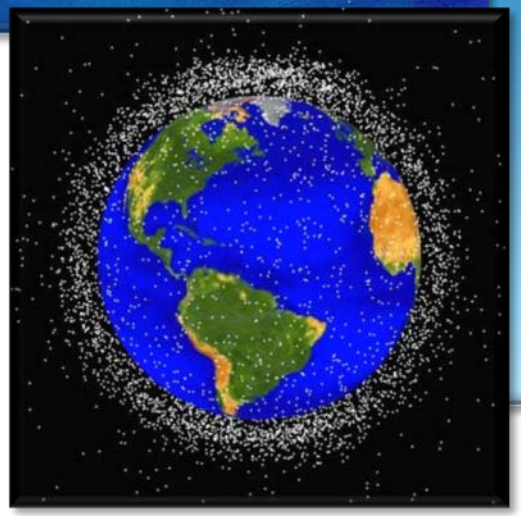
Global SOS Observations

System-of-Systems (SOS) thinking and development also occurs outside aerospace and defense

- Security and Surveillance
  - The Strait of Malacca
    - Maritime Surveillance
  - United Kingdom and European Union
    - London
    - Madrid
- Transportation Control and Management
  - The Strait of Malacca
    - Marine Electronic Highway
  - The London Congestion Charge System
- Electronic Commerce
  - Amazon
  - Google

V&V of System of Systems





How are we going to verify and validate these systems?

Increasing Complexity and V&V

- 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?

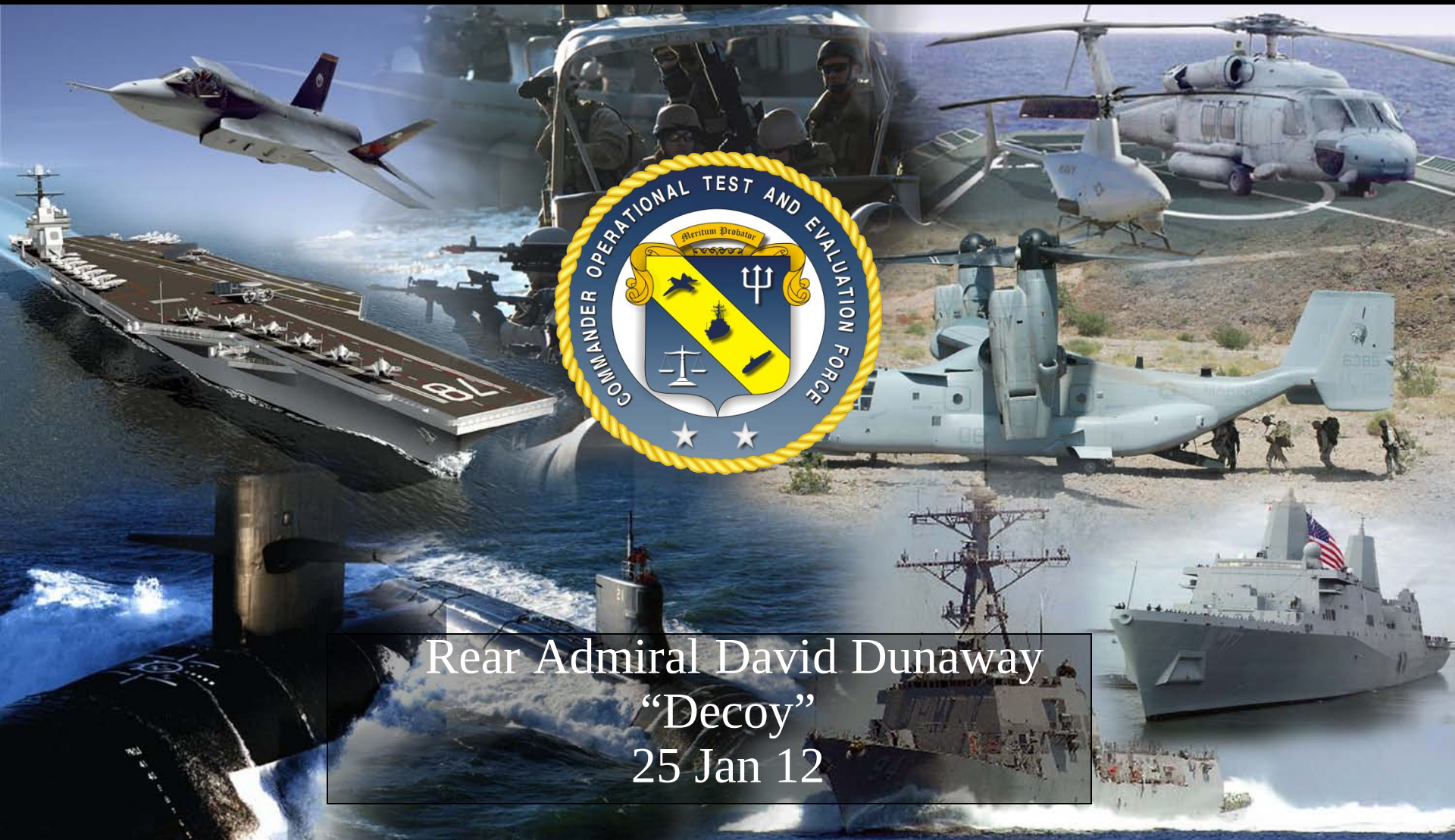
- An expectation during operational testing
  - "Once a system has been **demonstrated in an operationally relevant environment**, it may enter the Production and Deployment phase."–DOD
  - "Address critical issues regarding a system's performance in **combat-like environments when operated by field 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.

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?

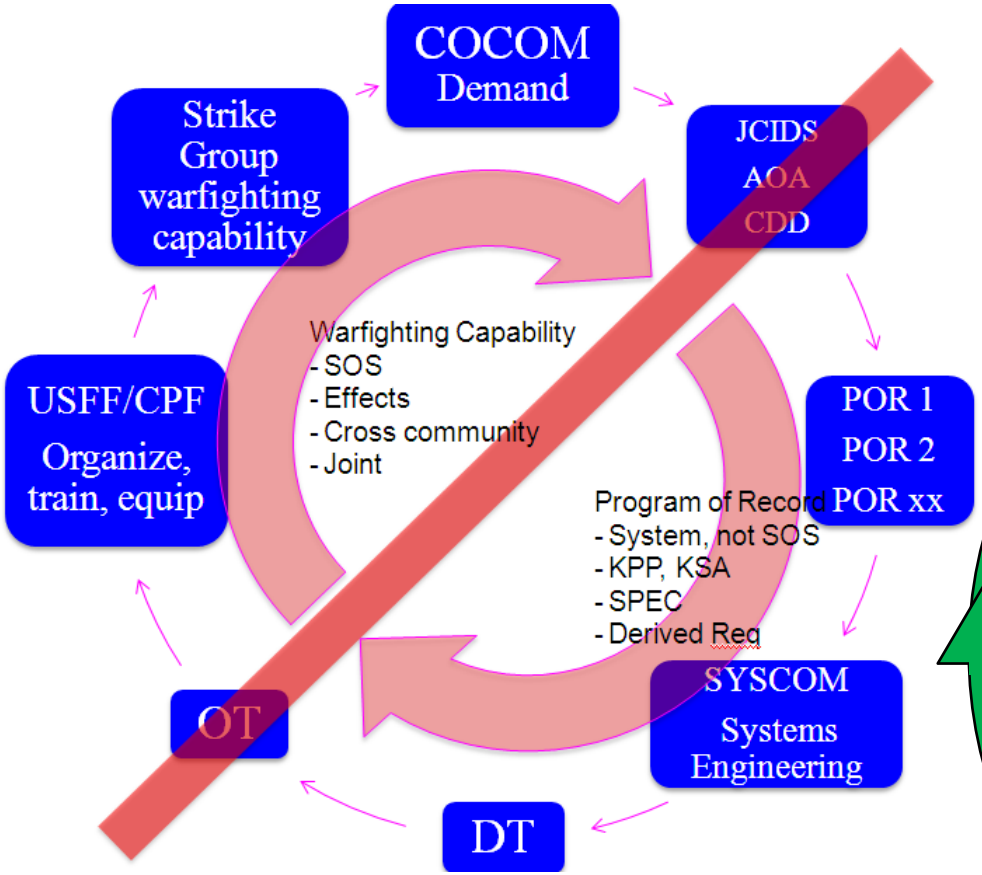
COMOPTEVFOR

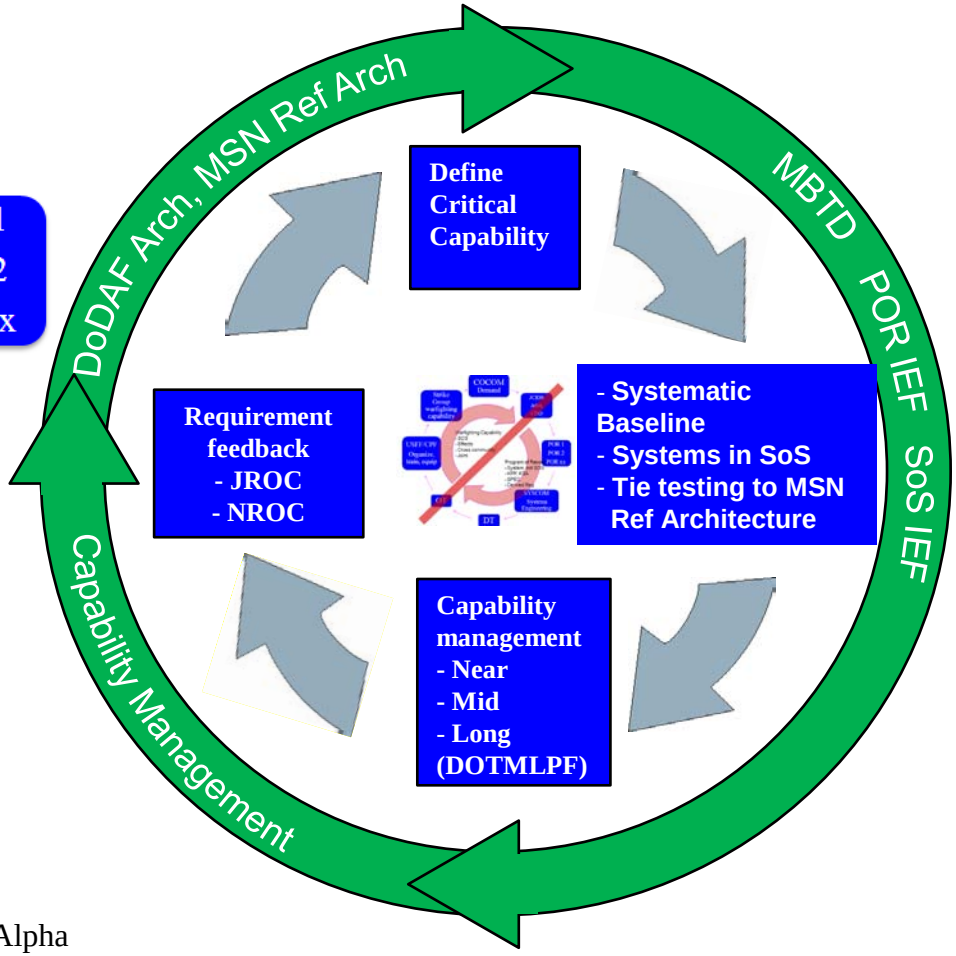


Rear Admiral David Dunaway
"Decoy"
25 Jan 12

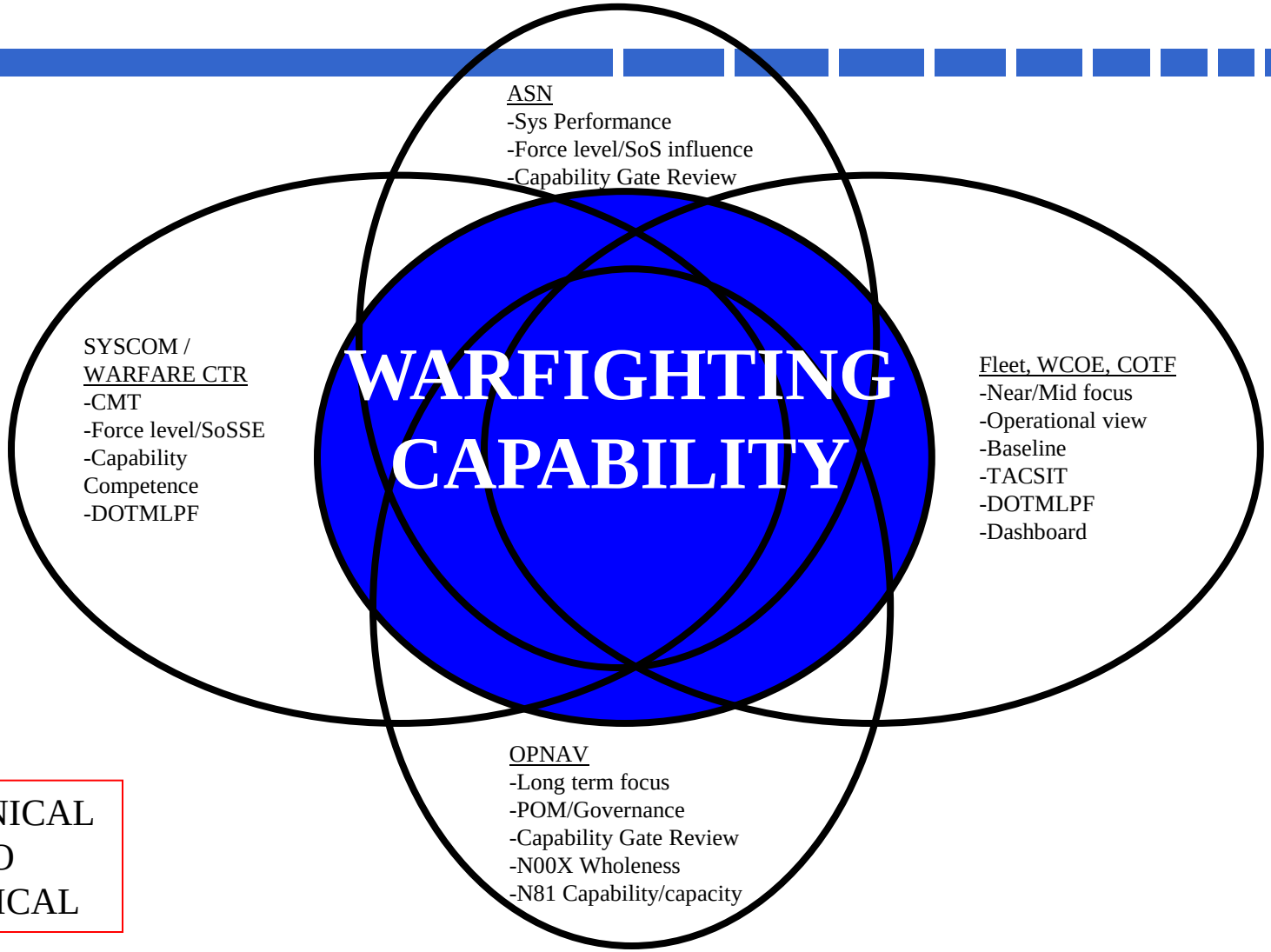
Systems must work as a System-of-Systems to create Warfighting Effects

Baseline Capability Management Governance





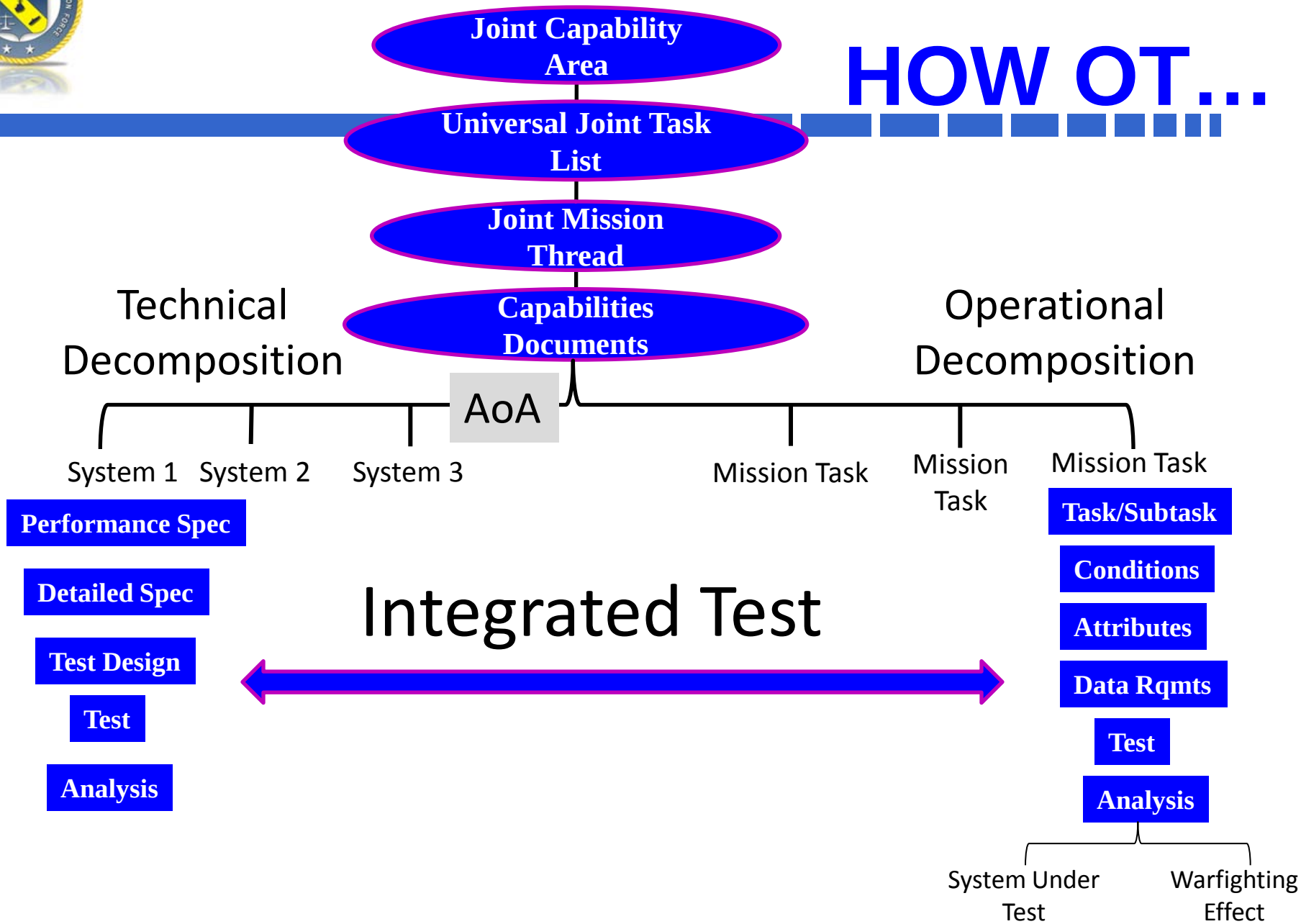
I&I Contribution



TECHNICAL
TO
TACTICAL

Horizontal Focus on Capability vice Vertical View on a System

HOW OT…


Joint Capability Area
Universal Joint Task List
Joint Mission Thread
Capabilities Documents
AoA
Technical Decomposition
Operational Decomposition
System 1
System 2
System 3
Mission Task
Mission Task
Mission Task
Performance Spec
Detailed Spec
Test Design
Test
Analysis
Integrated Test
Task/Subtask
Conditions
Attributes
Data Rqmts
Test
Analysis
System Under Test
Warfighting Effect

Task-Measure-Condition (SUW) (IEF Example)

Mission task	1st Level Subtasks	2nd Level Subtask	Measures	Conditions
2.1-Perform Surface Warfare (SUW)	2.1.8-Search Assigned Areas	2.1.8.1-Detect Contacts	M46 / M50 / M52 / M53 / M54 / M55 / M56 / M68 / M94 / M98 / M99 / M100 / M102 / M103 / M105 / M106 / M143 / M176 / M177 / M178 / M179 / M180 / M182 / M306 / M309 / M337 / M338 / M340 / M387 / M388 / M389 / M390 / M409 / M413 / M415 / M420 / M424 / M427 / M428 / M429 / M430 / M474 / M475 / M476 / M487 / M488 / M489 / M494 / M495 / M496 / M497 / M499 / M545 / M546 / M547 / M548 / M549 / M550 / M551 / M552 / M553 / M554 / M555 / M556 / M557 / M558 / M559 / M560 / M561 / M562 / M563 / M564 / M565 / M566 / M567 / M568 / M569 / M570 / M571 / M572 / M573 / M574 / M575 / M576 / M577 / M578 / M579	C 1.2 - SEA
				C 1.2.1.3 - Sea State
				C 1.2.6 - Shipping Presence
				C 1.2.6.2 - Shipping Type
				C 1.3.1.3 - Weather
				C 1.3.2 - Visibility
				C 1.3.2.1 - Light
				C 2.3.1.6 - Communications Connectivity
				C 2.6.6 - Target Range
				C 2.6.8 - Target Thermal Contrast
				C 2.6.9 - Target Size
				C 2.6.10 - Target Speed
				C 2.6.12 - Target Density
				C 4.12 - Supporting Vessels
				C 4.13 - Supporting Aircraft
				C 4.15 - Target Type
				C 4.43 - Sortie Type
				C 4.64 - Target Emitting
		2.1.8.2-Track Contacts	M46 / M50 / M52 / M53 / M54 / M55 / M56 / M68 / M94 / M98 / M99 / M100 / M102 / M103 / M105 / M106 / M143 / M176 / M177 / M178 / M179 / M180 / M182 / M309 / M337 / M338 / M340 / M387 / M388 / M389 / M390 / M409 / M413 / M415 / M420 / M424 / M427 / M428 / M429 / M430 / M474 / M475 / M476 / M487 / M488 / M489 / M494 / M495 / M496 / M497 / M499 / M545 / M546 / M547 / M548 / M549 / M550 / M551 / M552 / M553 / M554 / M555 / M556 / M557 / M558 / M559 / M560 / M561 / M562 / M563 / M564 / M565 / M566 / M567 / M568 / M569 / M570 / M571 / M572 / M573 / M574 / M575 / M576 / M577 / M578 / M579	C 1.2 - SEA
				C 1.2.1.3 - Sea State
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				C 4.43 - Sortie Type

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

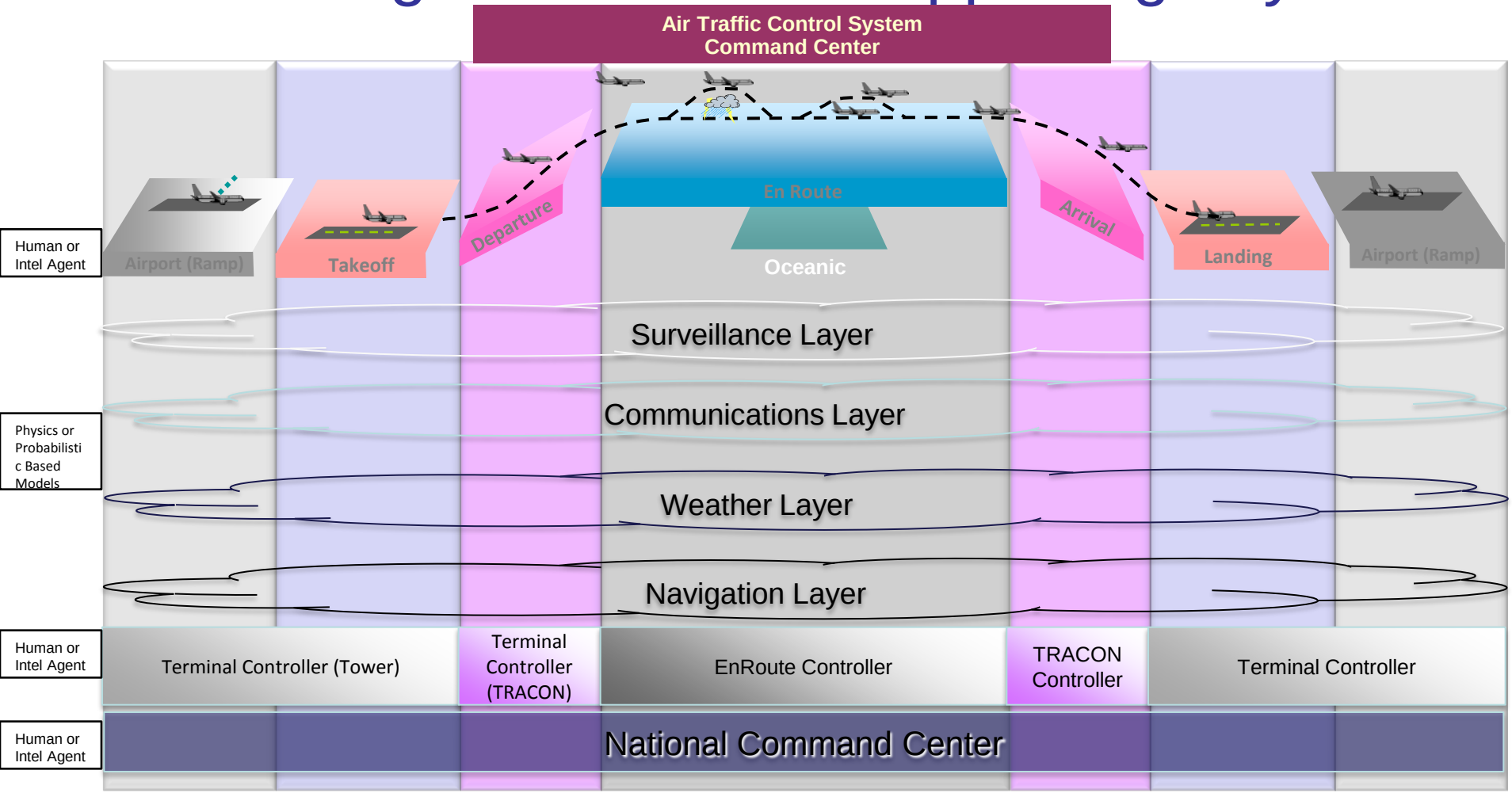
Federal Aviation Administration

Presented To: ITEA SoS Conference

By: Maureen Molz

Date: January 24-27, 2012

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

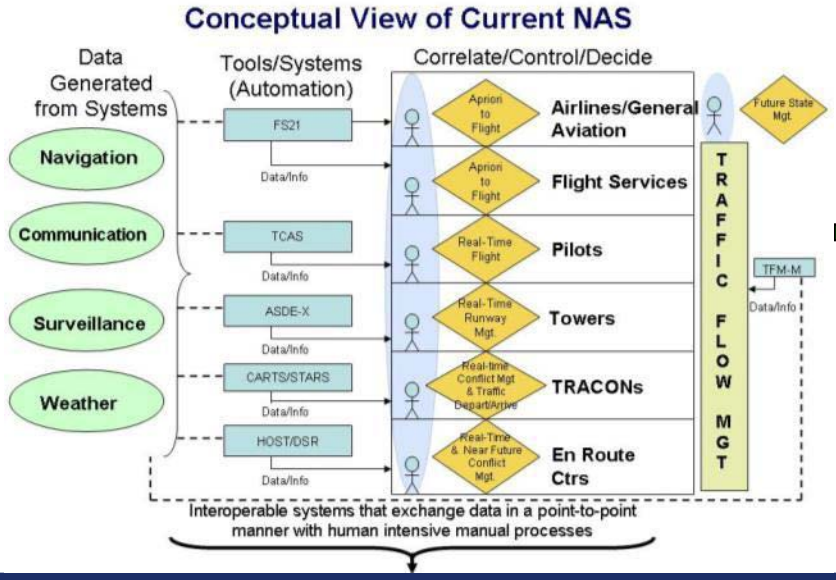
National Airspace System (NAS)

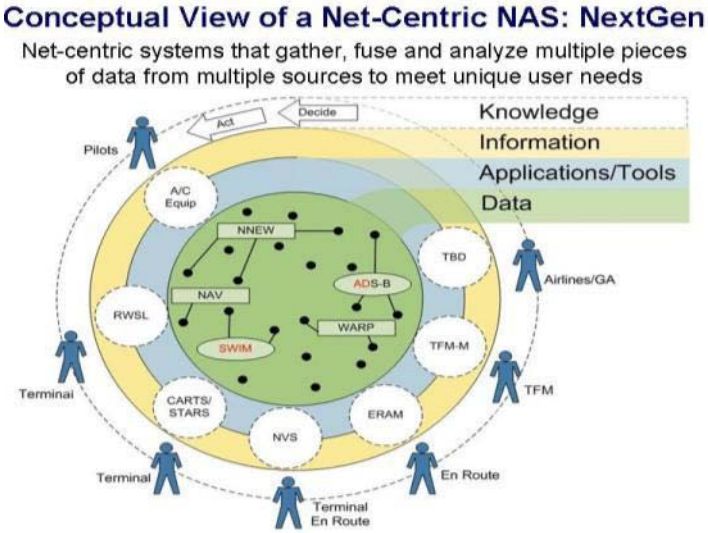
- **Largest most complex airspace system**
- **Serves civilian and military**
- **Evolved through pioneering, legislation, technological leaps, commerce, accidents and regulation**
- **Features hub and spoke, structured airspace, various equipped aircraft, capacity limitations**
- **Labor intensive**
- **Safety record (2006-2010)**
  - General aviation (7.11 accidents/100,000 flight hours)
  - Commercial aviation (0.149 accidents/100,000 flight hours)
  - Availability = .99999

The test challenge for the FAA

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





NextGen Cultural Challenges

- NAS was built by bolting on capability
- Safety first => avoid risk => resist change
- All facilities in NAS have unique SW versions and interfaces
- Users are Airlines (profitability)
- Air Traffic Controllers unionized
- Research arm exists in NASA (separate Gov't agency)
- FAA RDTE labs are interconnected, but stovepiped
- T&E is not independent
- Can never turn the NAS off: 24/7 operations

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

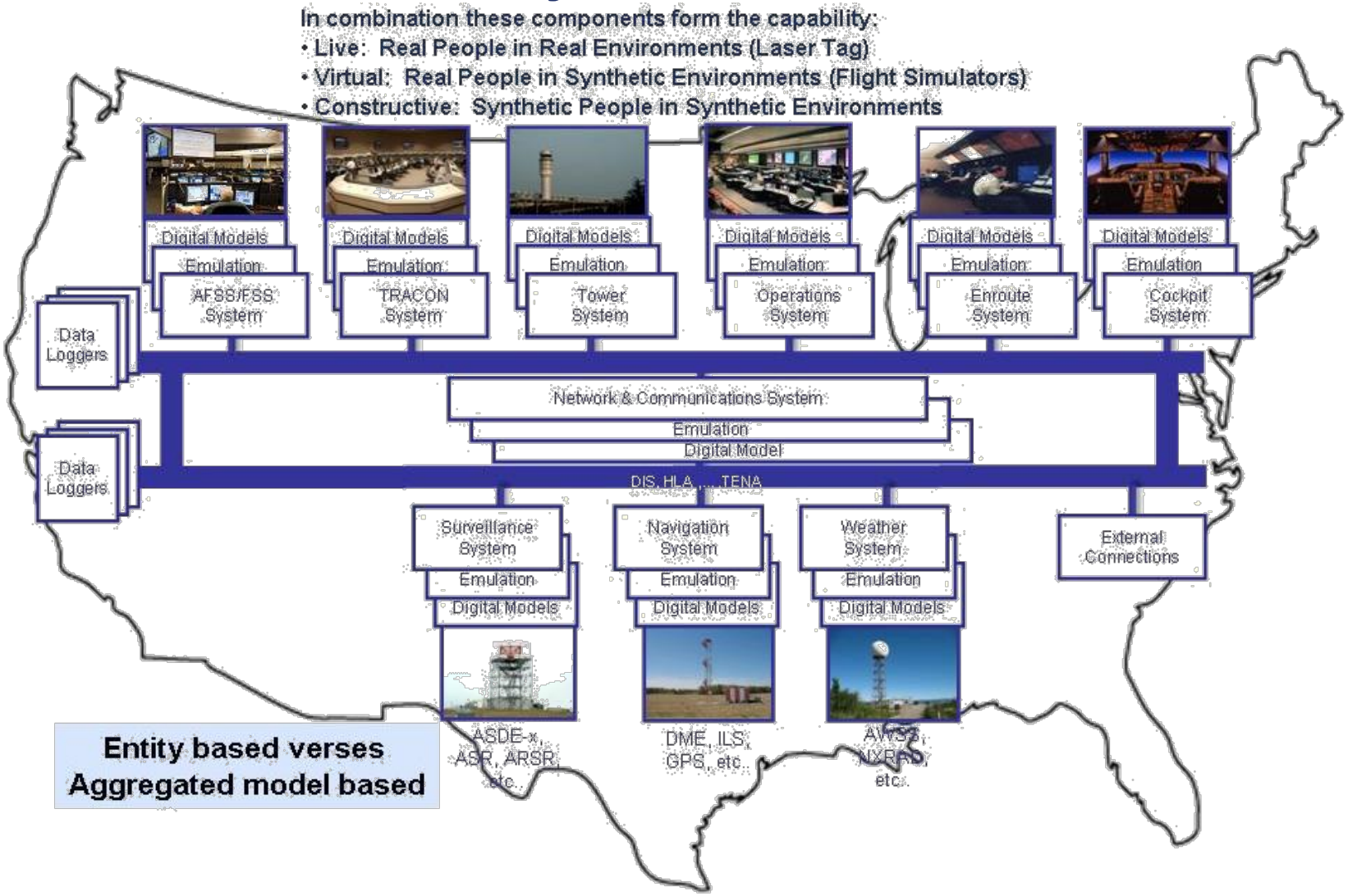
Approaches to SoS V&V

- **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.**

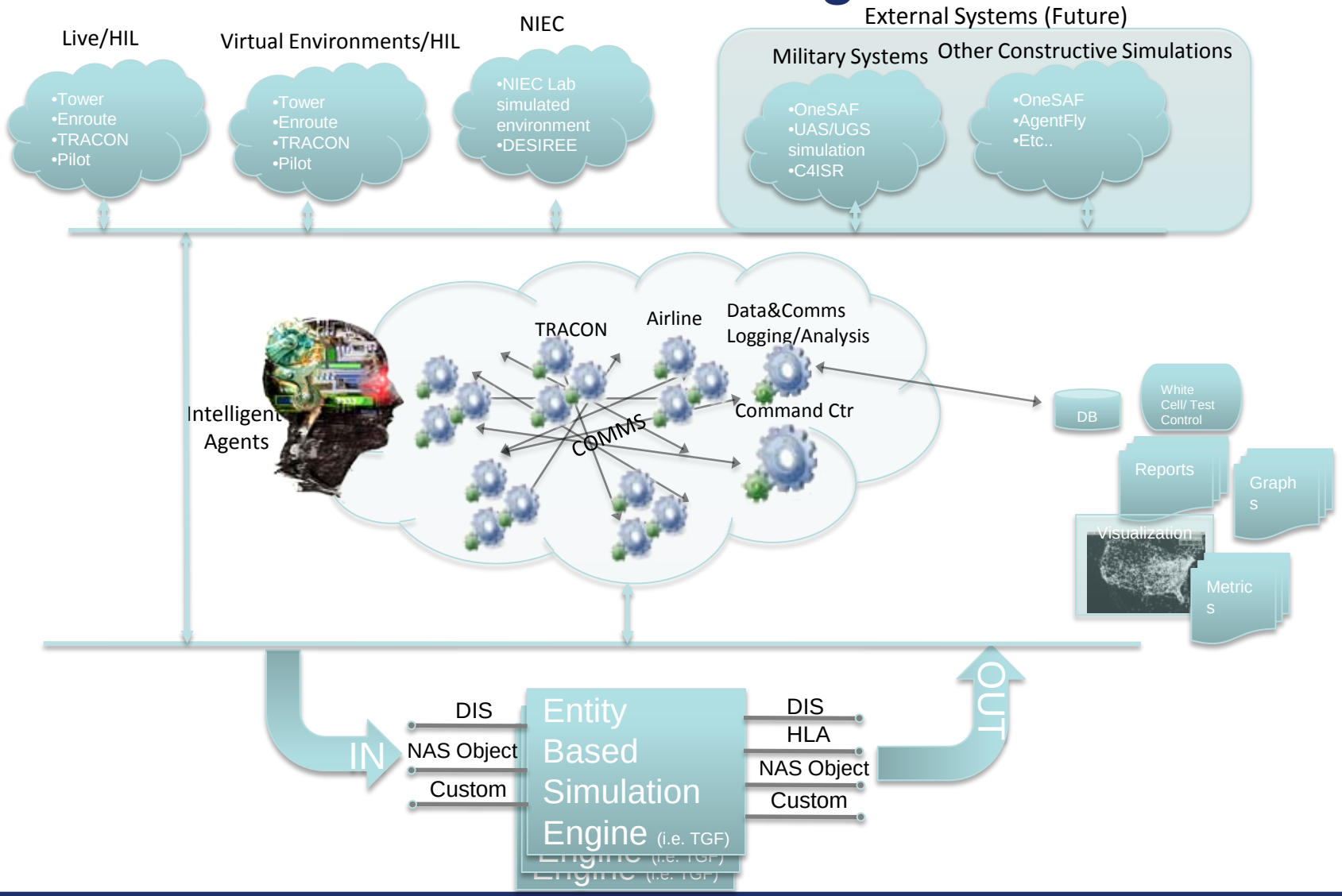
System-of-Systems (SoS) Assessment Platform

Create a real-time NAS simulation environment to support complex systems of systems research, system engineering, and test across all functional areas that is non-proprietary, scaleable, flexible, and allows real-systems to be submerged into the environment

System of Systems V&V Capability
NextGen Synthetic Environment



SoS Assessment Platform
Architecture Diagram



SoS Assurance

John Goodenough

January 2012

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

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?

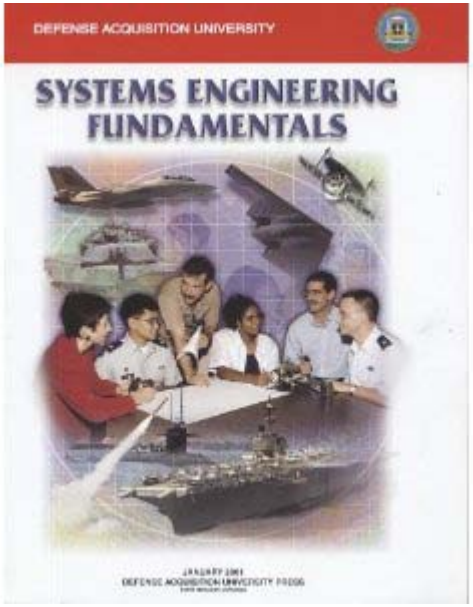
Test as We Operate

- "Live Fire Testing" in space - Really?
- Space Systems <u>are</u> Systems of Systems
  - Space Segment
  - Ground Segment
  - User Segment
- Each segment is a system
  - Each segment is often a separate contract
  - Tested independently first
  - Tested as a system next
    - Use ConOps to start
    - ICDs capture intersegment/inter-contract reqs
    - V&V set up for each level of testing

Biggest Issue - Requirements

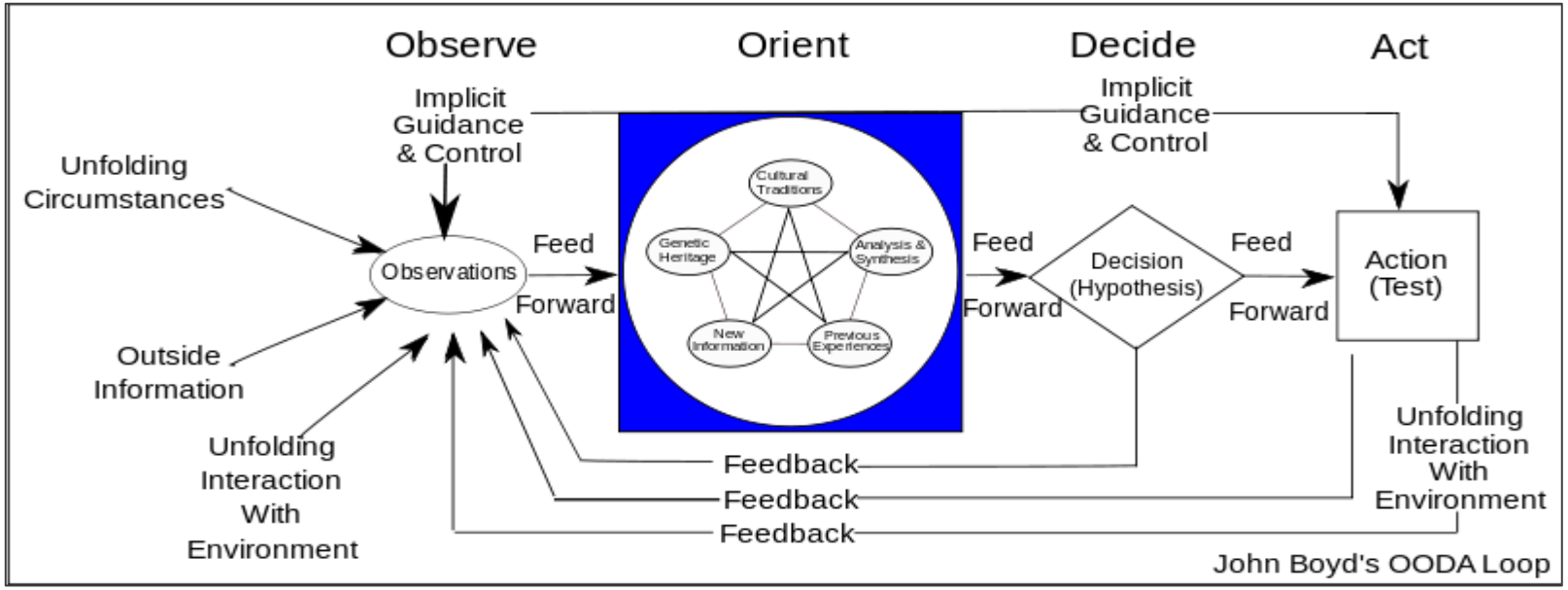
- Get the requirements right and the rest will follow
- "Back to Basics" – Testable requirements!
- Inspection, Demonstration, Analysis and Test
- Culture of Delta Milestone reviews
  - TBx's are OK, aren't they?
  - The fallacy of the closure plan
- CCBs – if cost/schedule not included

Get this book!



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 – <u>Update it regularly</u>
    - What?
    - When?
    - How?
    - How much?
  - SE at SoS level provides framework – <u>establish requirements</u>
  - Obtain user feedback
- T&E "grounded" in requirements
- Live test optimal – Is it affordable?
- SoS SE & TE team rep fielded – NRO field reps

We Never Forget Who We're Working For…

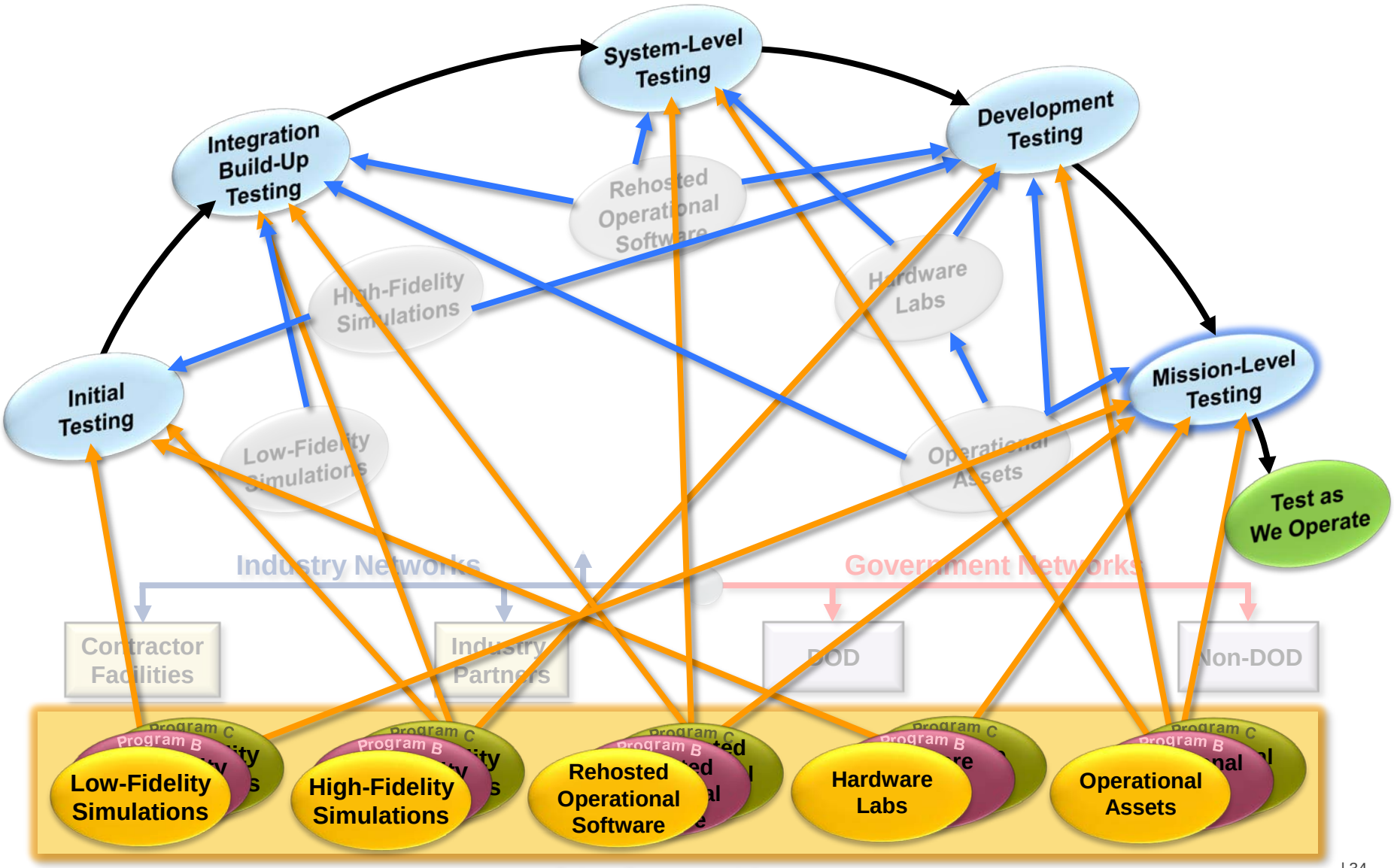
Mr. Jeff Thoman

Manager, Integration Test Range
Boeing Test and Evaluation

Industry Perspective: Topics

- **To improve test as we operate (fight):**
  - **Keep a mission-level focus across the product test life cycle.**
  - **Ensure the availability of critical assets across programs.**
  - **Create a relevant complex test environment.**
  - **Change the test culture to meet complexity of the SOS test.**

Improving Test as We Operate



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

~•~

Questions

Bios

Kevin Knudsen, Boeing

Kevin Knudsen is the Boeing Enterprise Systems/System of Systems Test Capability Leader, Laboratory Test Operations, Boeing Test & Evaluation. In this capacity, Kevin has capability responsibility for Systems/System of Systems Test (S/SOS-T) at all locations within the Boeing Enterprise. The S/SOS-T Capability is an enterprise resource providing Boeing the ability and capacity to design, develop, build, and integrate systems and systems-of-systems products and services.

Kevin has 25 years of experience in aerospace. Kevin most recently held the position of Department Manager, Satellite Systems Test for the El Segundo site. Throughout his career, Kevin has served in Test Engineering and Management roles with process and execution responsibility for advanced power and energy technology systems, multiple rocket propulsion test programs, and satellite test programs. Kevin has been responsible for hazardous test activities at both company-owned and government locations.

Kevin's career milestones include leading the testing and development of advanced, high temperature liquid metal systems, hydrogen fuel cells for transportation and distributed power, leading the Delta IV RS-68 engine development testing at the AFRL (Edwards AFB), and leading the Terminal High Altitude Area Defense (THAAD) thruster and system development and qualification testing at the AFRL (Edwards AFB), while serving as the Boeing Test Site Manager at the Air Force Research Laboratory (AFRL) at Edwards Air Force Base.

Kevin holds a Bachelor and Masters degree in Mechanical Engineering from California State University at Northridge, and a Masters in Business Administration from the University of Phoenix.

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Rear Admiral David Dunaway

Rear Admiral David Dunaway was born in El Paso, Texas. He received his wings in April 1984 and subsequently served as a Selectively Retained Graduate flight instructor in Meridian, Miss. After completing FA-18 initial training, he served in VFA-151, aboard the USS Midway in Yokosuka, Japan, from 1986-1989, when he was selected for the U.S. Naval Test Pilot School Class 96, Patuxent River, Md.

Dunaway's test assignments include: VX-5 as the A-12 operational test director; F/A-18 branch head (during this tour, he was selected as an aerospace engineering duty officer); F/A-18 Weapon System Support Activity as the deputy for Test and Evaluation; and, VX-9 as the F/A-18E/F operational test director. In this position, Dunaway flew more than 200 developmental test missions and was selected as the Test Pilot of the Year.

His program management assignments include: PMA-265 as the F/A-18 Radar IPT lead for the APG-79 Active Electronically Scanned Array radar, for which he and his team received the 2003 Aviation Week and Space Technology Laureate Award in developing this state-of-the art radar; PMA-201 as the program manager for the Precision Strike Weapons program office, for which the JSOW program received the David Packard Award for innovative business practices; and, most recently, as the deputy program executive officer, Air Anti-Submarine Warfare, Assault and Special Mission Programs.

Dunaway served as the Commander of the Naval Air Warfare Center, Weapons Division China Lake and Point Mugu, Calif., and the Naval Air Systems Command Deputy for Test and Evaluation from September 2007 until January 2009. He currently serves as the Commander, Operational Test and Evaluation Force in Norfolk, Va.

Dunaway is a Class of 82 graduate of the U.S. Naval Academy and holds a Bachelor of Science in Mechanical Engineering, a Master of Science in Aviation Systems Management from the University of Tennessee and a Master of Science in Aerospace Engineering from the Naval Postgraduate School. His personal decorations include the Legion of Merit, Meritorious Service Medal, Navy Commendation Medal and the Navy Achievement Medal. He has accrued more than 2,900 flight hours and 290 arrested carrier landings.

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Maureen Molz, FAA

Maureen Molz is the Manager of the Verification & Validation (V&V) Strategies and Practices Team in the test organization at the Federal Aviation Administration William J. Hughes Technical Center.

Maureen is responsible for the development of a comprehensive V&V approach that incorporates test and evaluation (T&E) policies and standards, a robust V&V infrastructure, and a credentialed T&E acquisition workforce.

She recently served as the Acting Manager of the Technical Strategies and Integration organization. In this capacity, Maureen was responsible for business and strategic planning and analyses; V&V; and technology transfer and information exchange from the Federal Laboratory to industry, academia, and other government organizations.

Maureen has 23 years of acquisition experience with the Army, holding positions in all phases of the Department of Defense (DoD) acquisition life cycle from research through fielding of systems.

Maureen holds a bachelor's degree in electrical engineering from Widener University, Chester, PA; a master's degree in electrical engineering from Drexel University, Philadelphia, PA; and a master's degree in strategic studies from the Army War College in Carlisle, PA.

She has received the following civilian service awards: Army Achievement Medal, Commander's Award, and two Superior Civilian Service Awards.

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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.

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John Varljen, Lockheed Martin

John is the Lockheed Martin Space Systems Company Test Engineering Director and the Assembly, Test and Launch Operations (ATLO) Chief Engineer.

He is a retired Lieutenant Colonel, and has enjoyed a distinguished Program/Engineering Management career in the US Air Force and LMSSC leading the planning, staffing, budgeting, technology, and operations of National Security Space programs.

He is an expert in cross-functional team building and leadership, multi-cultural communications, change management, organization development, and quality/performance improvement.

During his career, John worked on the GPS I, II, IIA, IIR and III satellites. He was the customer space vehicle systems engineer on the Military Support Program, test engineering lead on a SAP program and served as the customer Program Manager for the Defense Meteorological Satellite Program Flight 17 launch.

John has a Bachelor of Science in Aerospace Engineering from the University of Arizona and a Master of Science in Systems Management from the Air Force Institute of Technology.

He also holds an FAA Airline Transport Pilot's License and is a Certified Flight Instructor with Single and Multi-engine Land, Instrument Airplane ratings. John resides in Denver, Colorado.

John.E.Varljen@lmco.com

Jeff Thoman, Boeing

Jeff Thoman is the founding manager of Boeing's Integration Test Range which focuses on enterprise testing of SoS efforts in a distributed live-virtual-constructive environment.

Jeff has over 25 yrs experience all with Boeing predominately in test across a broad background of programs including Strategic Defense Initiatives Space base efforts, Strategic Nuclear Missile, Commercial Flight Test and Tactical Fighters.

Jeff has a Mechanical Engineering Degree from the University of Iowa.

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