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# **Test and Evaluation Issues for Systems of Systems: Sleepless Nights to Somnifex**

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# Sleepless Nights: Test and Evaluation for SoS

- **Systems of Systems Topics Discussed in 2009:**
  - Compiled list of “what keeps me awake at night” topics for SoS
  - Test and evaluation for SoS topped the “Sleepless Nights” list
- **NDIA SoS and DT&E Committees Worked Jointly in 2009:**
  - Identified key T&E challenges for SoS
  - White paper described 5 top issues
  - Presented at 2009 NDIA SE Conference in joint SoS/T&E track
- **Focus for 2010: Joint Workshop**
  - Define a path from Sleepless Nights to Sominex
  - Evaluate challenges and underlying issues
  - Transition specific issues into strategic initiatives
- **Workshop Held August 17<sup>th</sup>**
  - 3 Strategic Initiatives
  - 1 Collaborative Go-Do

**Workshop Defined Path to Sominex**

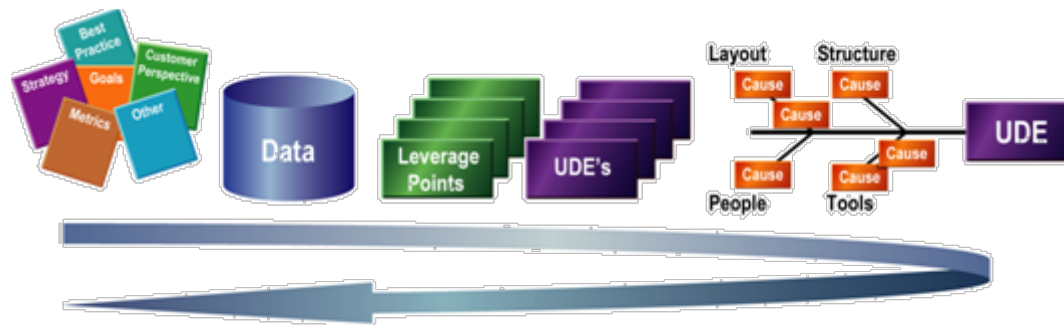
# Reminder from 2009: T&E Challenges for SoS

- 1) **Future T&E:** If SoS are not programs of record (and not subject to T&E regulations) why should we worry about this at all?
- 2) **Requirements:** If 'requirements' are not clearly specified up front for a SoS, what is the basis for T&E of an SoS?
- 3) **Metrics:** What is the relationship between SoS metrics and T&E objectives?
- 4) **Systems Changes:** Are expected cumulative impacts of systems changes on SoS performance the same as SoS performance objectives?
- 5) **End to End Testing:** How do you test the contribution of a system to the end to end SoS performance in the absence of other SoS elements critical to the SoS results? What if systems all implemented to their specification, but the overall SoS expected changes cannot be verified?

**White Paper was Starting Point**

# Facilitated Workshop: The Technique

Data Collection:  
SoS White Paper  
SE Conference Papers

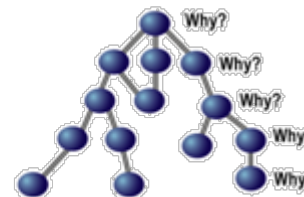


Potential Problem Areas

- 1) *Future T&E for Systems brought together as SoS*
- 2) *Requirements*
- 3) *Metrics*
- 4) *Systems Changes*
- 5) *End to End Testing with systems not yet available*

**Benefits**  
Savings \$\$\$ & Other Benefits  
Cost of Implementation  
Plan

**Opportunities**  
1.  
2.  
3.  
4.



Potential Causes  
If we could only fix one thing,  
it would be \_\_\_\_\_

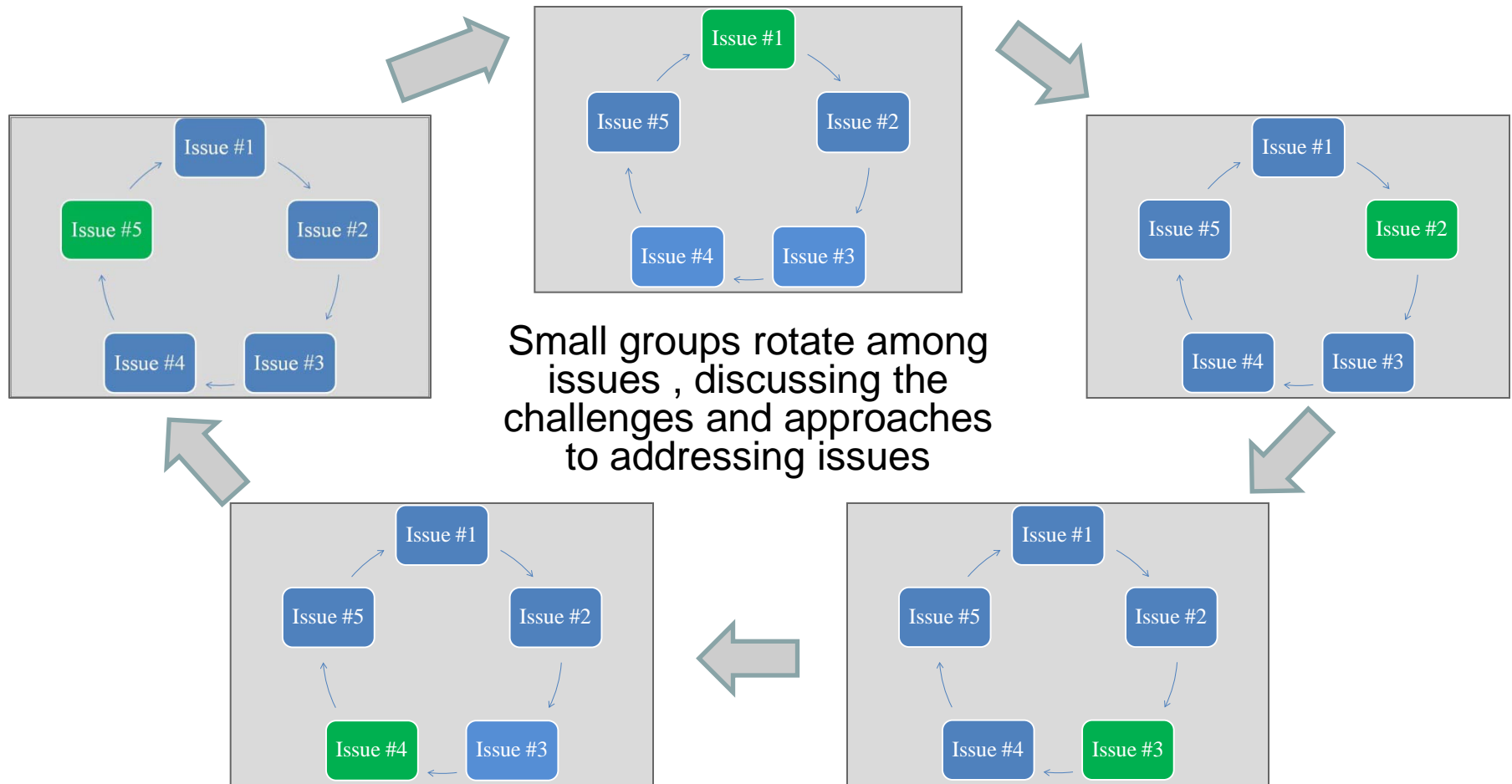
Improvement Areas:  
Strategic Initiatives  
Collaborative Go-Do

		Cable	Tasks	Setup	Testing	Security
Facility	Signal cables wrong length or incorrect	X		X		
	Power/Cooling connections	X		X		
	Safety interconnect	X				
	Test equipment			X		
Schedule Dependencies	Equipment in NFR	X	X	X		X
	Signal cable delivery	X	X			
	REV/NBDCSP availability		X		X	
	REX array availability		X		X	
Security	Test results prior to string integration				X	
	Detailed tests for integration/dep	X	X	X	X	X
	Classified shipment					X
	Classified workstations					X
Integration Test Conduct	Classified field returns					X
	Procedures incomplete or incorrect		X	X	X	
	CSP simulator				X	
	Work-sounds required	X	X	X	X	X

Leverage Matrix  
Map Causes to problem areas

**Transition from Problem Space to Solution Space**

# Facilitated Workshop: Carousel Brainstorming



**Brainstorm Undesired Effects Aligned with Each Issue**

# Facilitated Workshop: Action Development

## Leverage Matrix

	Issue #1	Issue #2	Issue #3	Issue #4	Issue #5
Initiative A	X		X		
Initiative B		X			
Initiative C	X			X	X
Initiative D			X		
Initiative E					X

## Strategic Initiatives

Problem Statement  
 Examples of Problem  
 Candidate Vision Statement  
 Participants  
 Action Plan  
     Output Products  
     Deadline for Completion

## Collaborative Activities

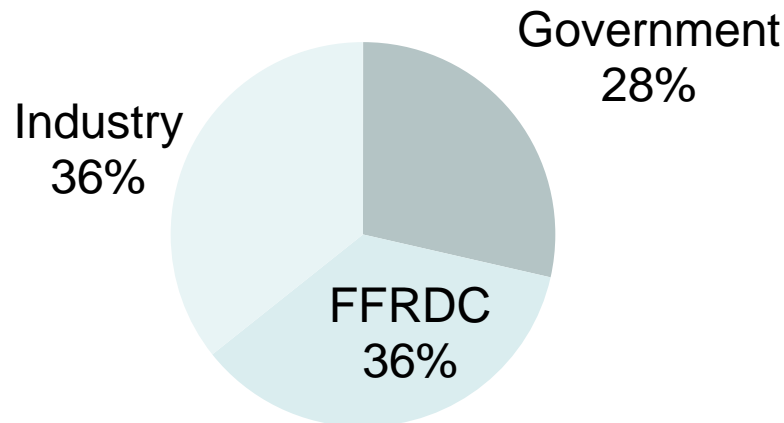
Collaborative Go-Do Activity  
 Participants  
 Action Plan  
     Output Products  
     Timeline for Completion

Approaches to addressing the issues are recast as initiatives and collaborative activities

**Define Strategic Initiatives and Collaborative Activities**

# Facilitated Workshop: Attendees

Mr. Robert Aaron	Army	Government	Dr. JoAnn Lane	USC CSSE	Industry
Col (Ret) Suzanne M. Beers	MITRE	FFRDC	Mr. Steven S. Lee	DoD	Industry
Dr. William D. Bell	MITRE	FFRDC	Mr. Marty Leek (Facilitator)	Raytheon	Industry
Mr. Aumber Bhatti	MITRE	FFRDC	Mr. Favio L. Lopez	Army	Industry
Clyneice Chaney	MITRE	FFRDC	Mr. John R. Palmer	Boeing	Industry
Mr. Peter H. Christensen	MITRE	FFRDC	Mr. George Rebovich Jr.	MITRE	FFRDC
Mr. David W. Coleman	MITRE	FFRDC	Mr. Frank J. Serna	Draper	Industry
Dr. Judith S. Dahmann	MITRE	FFRDC	Mr. Michael Shanahan	USMC	Government
Ms. Indira Deonandan	MIT	Government	Dr. Carol A. Sledge	SEI	FFRDC
Mr. John W. Diem	OSD/ MSCO	Government	CDR (Ret) James D Smith II	SEI	FFRDC
Mr. Mark E. Fenicle	DoD	Government	Mr. Thomas Wissink	Lockheed Martin	Industry
Mr. Tanya Gobel	SAIC	Industry	Mr. Jack Zavin	OSD NII/DoD CIO	Government
Mr. Robert Heilman	DOD	Government	Dr. Janice A. Ziarko	MITRE	Industry
CDR (Ret) Bryan Herdlick	JHU APL	Government	Ms. Robin E. Ziradinovic	SAIC	Industry



# Workshop Results

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- **Strategic and Tactical Initiatives Identified**
  - Consensus among participants
  - Willing leadership
- **Three Strategic Initiatives:**
  1. Best Practices Model for SoS T&E
  2. Radical Approach to SoS T&E
  3. SoS Governance
- **One collaborative ‘Go-Do’**
  1. SoS SE Policy and Guidance

**Initiatives Identified with Action Plans**



# Collaborative Go-Do: SE Policy and Guidance

*Ensure that guidance for SoS SE (DoD SoS SE Guide) is recognized and employed on growing number of SoS*

- **Good Results:**
  - Most participants are aware of current DoD guidance on SoS SE
  - A number have applied the guidance with good results
- **The current guidance is ‘soft’:**
  - Provides recommended approaches to addressing SE for SoS
  - Core elements of SoS SE reflected in the discussions of the workshop issue groups as things which need to be done to address the issues
- **No requirement to follow this guidance:**
  - An obstacle to success is that there is no requirement to follow this guidance
  - Without this, the imperative, the authority and resources needed to successfully address technical issues critical to employing SoS SE to enable user capabilities is missing

**Recognize and Employ SoS Guidance**

# Strategic Initiative #1: Best Practices Model for SoS T&E

*SoS T&E as a continuous improvement process supporting capabilities and limitations information for end users and feedback to the SoS and system SE teams toward evolution of the SoS*

- **Lead:** Rob Heilman and Judith Dahmann
- **Product :** Description of “best practice” model, supporting evidence based on use cases, from DoD and beyond (if possible); (non government, commercial) with an assessment of efficacy and applicability of the model including degree of confidence
- **Who/Customer:** DDR&E, SE/DE, TRMC
- **When:** Oct 2010 – Dec 2011
- **How/Activities:**
  - **Oct – Dec 2010:** : Form team; Review with customers to determine interest in product; Develop plan, present plan at strategic planning meeting, and circulate model draft as baseline
  - **Jan – Aug 2011:** Identify use cases and schedule presentations/exchanges as part of committee meetings
  - **Sept – Dec 2011:** Assess model against use case data; Synthesize and evaluate

**Define Best Practices Model**

# Strategic Initiative #2: Radical Approach to SoS T&E

*Rethink T&E of systems in an operational context and systems interoperability away from system testing toward integrated 'capability' SoS testing*

*Investigate the concept of replacing DT, OT, NR-KPPs, etc. with an overall SoS capability test. Take results to end user. Sell concept to DOT&E and acquisition communities*

- **Lead:** Tom Wissink
- **Product:** Report describing a process to achieve “capabilities test”
- **Who:** DT&E/OT&E communities & certification & acquisition groups, force providers
- **When:** November 2010 start (6-9 months completion)
- **How:** Series of Workshops

**Define SoS Capability Test**

# Strategic Initiative #3: SoS Governance

*Identify the process by which we can change and influence the governance of SoS*

*Mature/improve templates (AT&L) – defined minimum set of characteristics that are required to govern SoS T&E efforts*

- **Lead:** Robert Aaron and James Smith
- **Product :** ID the process to influence governance
  - ID what is Governance, minimum set
  - Rationale
- **Who:** Audience → Stakeholders → Supporters
- **When:** Milestones:
  - Info Oct 25-28 SE Engineering Conference Paper
  - Mid Jan 2010 draft
- **How:** Briefs – Feb → June
- **Issues:** Coalition partners; Other NDIA groups

**Define Characteristics of Successful SoS T&E**

# Summary

- **Successful Workshop with SoS and T&E Practitioners**
- **Framework Established for Continuing Collaboration**
  
- **Top 5 T&E Issues for SoS:**
  1. **Future T&E for SoS programs not currently program of record**
  2. **Requirements that become the basis of T&E for SoS**
  3. **SoS Metrics that relate to T&E objectives**
  4. **System changes that impact SoS performance and T&E objectives**
  5. **End to End Testing of SoS elements**
  
- **Initiatives to Develop T&E Solutions for SoS:**
  1. **Define a best practices model**
  2. **Define SoS capability test**
  3. **Define characteristics of successful SoS T&E**
    - **Recognize and employ existing guidance for SoS (DoD SoS SE Guide)**

**Transition Discussion from Challenges to Solutions**

# BACKUP

## Details on T&E Issue Discussions

# Issue 1

## If SoS are not programs of record (and not subject to T&E regulations) why should we worry about this at all?

### Discussion

- **Restatement of issue:**
  - How do we define, articulate, and enforce the relationship between the SoS and the constituent systems?
  - How does T&E support/help this?
- **Governance/Roles/Stakeholders**
  - Need a shepard (architect?) and support from users
  - Need to educate stakeholders
  - What are rules of governance?
  - What are the regulations, standards, and policies?
  - Need to obtain resources (funding, test assets, time)
  - SoS leadership focus: architecture views, who “owns”
  - Potential conflicts between SoS and constituents
  - Business case for PMs to do SoS
- **SoS T&E Focus**
  - SoS T&E operationally driven (vs. DT-ish)
  - SoS edge of the envelop
  - What is an AoA of SoS?
  - Emergent behaviors (good and bad)
  - SoS resource consumption (e.g. data pipeline)
  - Continual assessment (joint exercises, deployments)
  - How to define test strategies to efficiently continuously test?
  - How do we help the T&E process help the SoS work?
- **Understand SoS Capabilities**
  - What is the SoS expected to do?
  - Define and articulate relation between SoS and systems
  - Flexible composition
  - Artfully sub-optimize the systems in favor of the SoS
  - System performance bounds are not rigid in real operation
  - Candidate solution: SoS requirements document with annex for each constituent system (what is constituent contribution to SoS capability)

# Issue 1      If SoS are not programs of record (and not subject to T&E regulations) why should we worry about this at all?

## Approach to addressing issue

- Define a minimal set of SoS governance characteristics of a successful acknowledged SoS
  - Roles/resources
  - Rules/regs/standards/policies
  - Managing conflicts
  - Establishing cooperation of constituent systems
  - Includes responsibility to define SoS capabilities, architecture, and associated test strategy
  - Concept of continual change and test in operational and training environment
  - Lean management, taking advantage of available opportunities
  - Recognize the large number of SoS across the DoD, and the fact that many systems support multiple SoS and the potential impacts of governance



# Issue #2      If “requirements” are not clearly up front from a SoS, what is basis for T&E of an SoS?

## Discussion

- Requirements vs expectations; Mission objective vs. technical requirements
- Mission threads linked to capability strands as architecture model
- Who/what has responsibility for architecture/requirement- another DOD layer?
- Standards for participating or acceptance of each system into SoS
- Requirements model for architecture encompassing time, space changes
- SoS level requirement T&E at program or SoS level balance?
- T&E of aggregation of systems level requirements (SoS level TEMP)
- Integrated development environment/reference architecture as model
- Need operations/architecture view of SoS that individual systems must plug into- need someone responsible for this
- Prioritization of SoS capabilities at high (OSD) level required to permit constituent PM to manage development and delivery. With funding at SoS
- Measure and baseline SoS capability thru T&E w/o requirements. Where do we get metrics?
- Must have an “enforcer” capability manager - carrots and sticks
- Measure SoS capabilities when changes to SoS Baseline
- CONOPs vs innovative use of systems in face of changing threat
- Move from paper to 4 dimensions to capture SoS capabilities requirements.
- Use of modeling tools of SoS components delivered with each component to communicate requirements
- Capability flow down to systems, demo meeting systems capability

## **Issue 2: If “requirements” are not clearly defined up front for a SoS, what is basis for T&E of an SoS?**

### **Approach to addressing issue**

- The DOD needs a top-down (architecture, requirements, context, expectation) flow-process to systems within the SoS
- Needs authority & funding to enforce capability fulfillment
- Needs to be flexible enough to meet changing needs and threats and CONOPS/operator innovation.
- Determine the right balance between system test to sos- test to SOS level test

# Issue 3      What is the relationship between SoS metrics and T&E objectives?

## Discussion

- SoS T&E is focused on continuous improvement of the SoS (as compared to system T&E which is focused on the field, fix, or don't field decision)
- Continuous SoS T&E requires
  - Stable/consistent metrics
  - Consistent approach to defining evolving baseline
  - A way to deal with emergent behavior (technical, organization, human) – positive or negative
  - Need to leverage wide range of opportunities for test environments
  - Continuous improvement means continuous testing ; Built in test instrumentation for feedback from field
- SoS metrics
  - Do not address discrete behaviors of systems (as do system metrics)
  - Do address end to end performance across systems in SoS toward capability objectives of the SoS
- What is objective of T&E for an SoS?
  - Development information on capabilities and limitations of SoS to inform end users and ongoing SoS evolution (as compared to system T&E which is assessment of whether system meets requirements)
- SoS T&E customers?
  - End user and SoS SE team (as compared to system T&E where acquisition community is the customer)
- SoS T&E should be risk driven: focus on areas of risk to SoS or systems

# Issue 3

## What is the relationship between SoS metrics and T&E objectives?

### Approaches to addressing issue

- Characterize SoS T&E as continuous improvement, document the approach and share with the community
- Radically change how we look at testing given the growing prevalence of SoS
  - Concepts of DT and OT don't really fit
  - Inefficient to address systems in operational SoS environment on a system by system basis (OT today)
  - Continue to test individual systems to assess whether we have developed what we asked for
  - Create a new approach to OT, by cross systems support for testing capabilities

# Issue 4

## Are expected cumulative impacts of systems changes on SoS performance the same as SoS performance objectives?

### Discussion

- To address these issues you need to fix
  - Define the SoS and its performance objectives
    - Constituent systems that are part of the SoS
    - Which parts of the constituents contribute to the SoS objectives
  - Describe the current and future state of the changing systems (Baselines)
  - Assign ownership of SoS performance objectives
  - Big challenge; leadership issue, etc
    - More collaborative approach for stakeholders of SoS
- Emergent behavior – interaction of systems, humans, system and organization along with constant change of the parts
- Bounds of human impact
  - Operator – leader – mission
  - The people side of systems
- Training and development of the evaluators (and the end users)
- Expensive to assess if capabilities are realized (hard to do)
  - Doing more with less?
  - Disconnect thinking and reality?
- Leadership understanding of SE and SoS
  - Is there competency to make decisions and know the impact and implications?
    - Trades without know the desired outcome can be achieved
  - Evaluation on an SoS basis vs individual systems and their acquisitions
  - Timing and who benefits (lack of rewards systems)
  - Accountability for SoS
- Continued improvement, assessment, and alignment because objectives have changed
  - More data from fielded systems
- Connections to fielded side of the house (doesn't deal well with change)
- “Measurement system” for system
  - Analysis of impacts
  - M&S?
  - Risks; “we are not sure but...” with some mitigation
  - Regression testing and configuration of SoS
  - Comparative analysis

## **Issue 4**      **Are expected cumulative impacts of systems changes on SoS performance the same as SoS performance objectives?**

### **Approaches to addressing issue**

- Influence assigning leadership responsibility and ownership of defined SoS capability and associate performance objectives
- Establish incentives of constituent systems to collaborate and achieve SoS performance objectives
- Map SoS capabilities and performance objectives to constituent systems (under configuration control)
- Continual assessment, improvement, and realignment is required (incremental approach) focused on end user)
- Create a guidance framework for emergent behaviors of changing to be measured and managed

# Issue 5

Are expected cumulative impacts of systems changes on SoS performance the same as SoS performance objectives?

How do you test the contribution of a system to the end to end SoS performance in the absence of other SoS elements critical to the SoS results?

## Discussion

- Trying to assemble all piece parts for T&E
- So many variables that can impact T&E outcome
- Reliance on other programs (e.g., JTRS) for capabilities that can slip in schedule or are never delivered
- Spanning “use-case” space with a reasonable set of resources and schedule
- Need defined set of requirements (but, of course, this is part of the problem space)
- What does a T&E strategy look like?
- How account for “the network” and stresses to it?
- DoD should require programs to share/ make transparent to other programs their development, DT and other data (obstacles: proprietary/security)
- Recommend ways to systems instrument to enable post-fielding collection of “test” data
- Operations, exercises, training
- DoD should develop a common approach to accounting for “the network” as a constituent of all SoSs for purposes of T&E
- DoD articulate purpose of SoS T&E
  - Is it a capability demo ( “what do we have?”)
  - Is it a classical check against requirements?
  - The real purpose of SoS T&E is to answer:
    - Is the new capability operationally useful (whether or not it “met” requirements); what are risks?
  - How can the new capability be used?
  - What further changes are required?

# Issue 5

Are expected cumulative impacts of systems changes on SoS performance the same as SoS performance objectives?

How do you test the contribution of a system to the end to end SoS performance in the absence of other SoS elements critical to the SoS results?

## Approach

- **M&S of piece parts that are not yet ready to be tested (but issues between M&S for individual system performance versus effects-based M&S) – potential solution to issue #1.**
- **Architectures and synchronizing them an enabler of T&E (provides well-defined baseline; can measure deltas against the baseline)**
- **Combinatorial test & design (suggested as potential solution to issue #2).**
- **Model-test-model approach suggested for way to accommodate emergent behavior**
- **Field exercises – instrumentation to collect data**
- **Training as a T&E opportunity**
- **No SoS requirement => no TEMP for SoS capabilities => no SoS T&E funding. Therefore need a capability (SoS) focused, cross-system, integrated test schedule that builds to a graduation-level event. (some disagreement re. existence of such an event). Push SoS T&E to fleet/operators as proof of IOC (need fleet experimentation funding).**