# Use of Operator in the Loop Simulations to Substantiate Metrics for Human-centric Systems

## How to capture the value / impact of System of Systems warfighters working together

*Date:* ***04 February, 2014***

*Presented to:*

**NDIA Human Systems Conference**

Personnel, Training, and Leadership Development Session

*Presented by:*

**CDR Justin Shoger, USN**

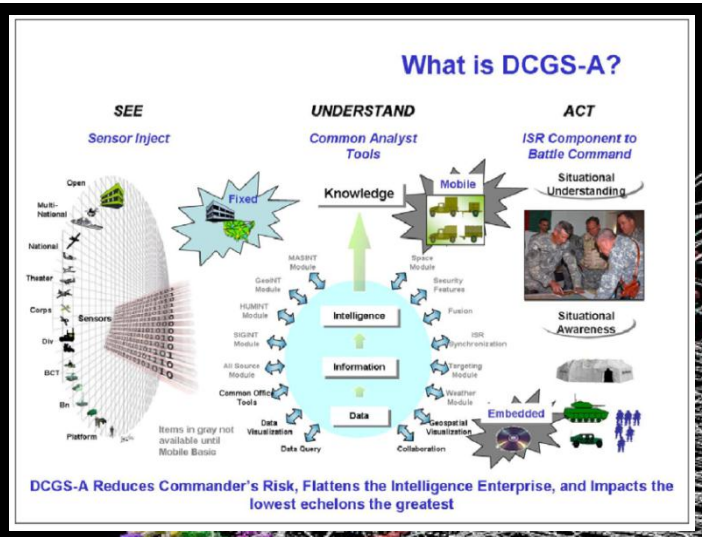
Live, Virtual, Constructive Architectures Lead, PMA205

# Introduction

- Topics
  - Measuring the warfighter contribution to a system of systems (SoS)-based capability
  - Actionable metrics for strategic and acquisition decision making
  - Use of operator-in-the-loop (OITL) events to mature and expand our military utility assessment approach to include decision making and human performance
- Take-Aways
  - Apply team macro-cognition work to develop actionable decision making metrics
  - Include the human and human performance as key aspects of warfighting SoSs to produce more effective capabilities
    - Planning and resourcing capabilities
    - Designing warfighting SoSs
- References
  - Department of Defense Systems Engineering Guide for Systems of Systems, 2008
  - Transferring Meaning and Developing Cognitive Similarity in Decision-making Teams: Collaboration and Meaning Analysis Process – Rentsch, et.al., 2010
  - Metrics for Supervisory Control System Evaluation – Cummings & Donmez, 2013

**Today's warfighter is not just a SoS integrating interface, but is a warfighting aggregator and the critical link in capability effectiveness**

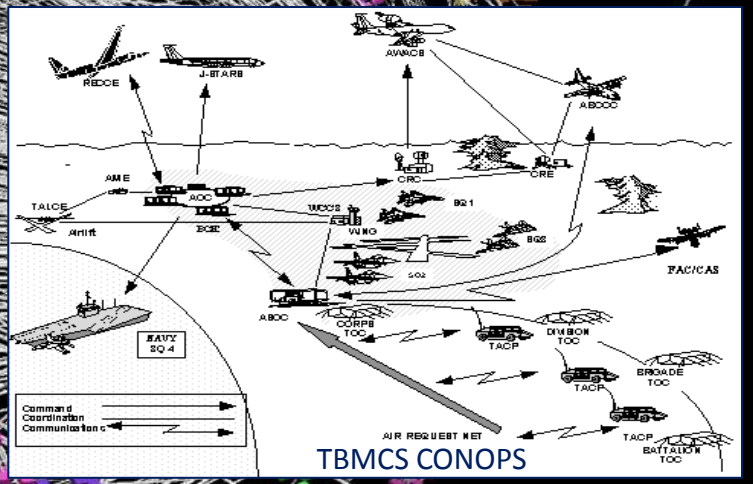
# Increasing Focus on Human Centricity




Triton

Fire Scout

LCS

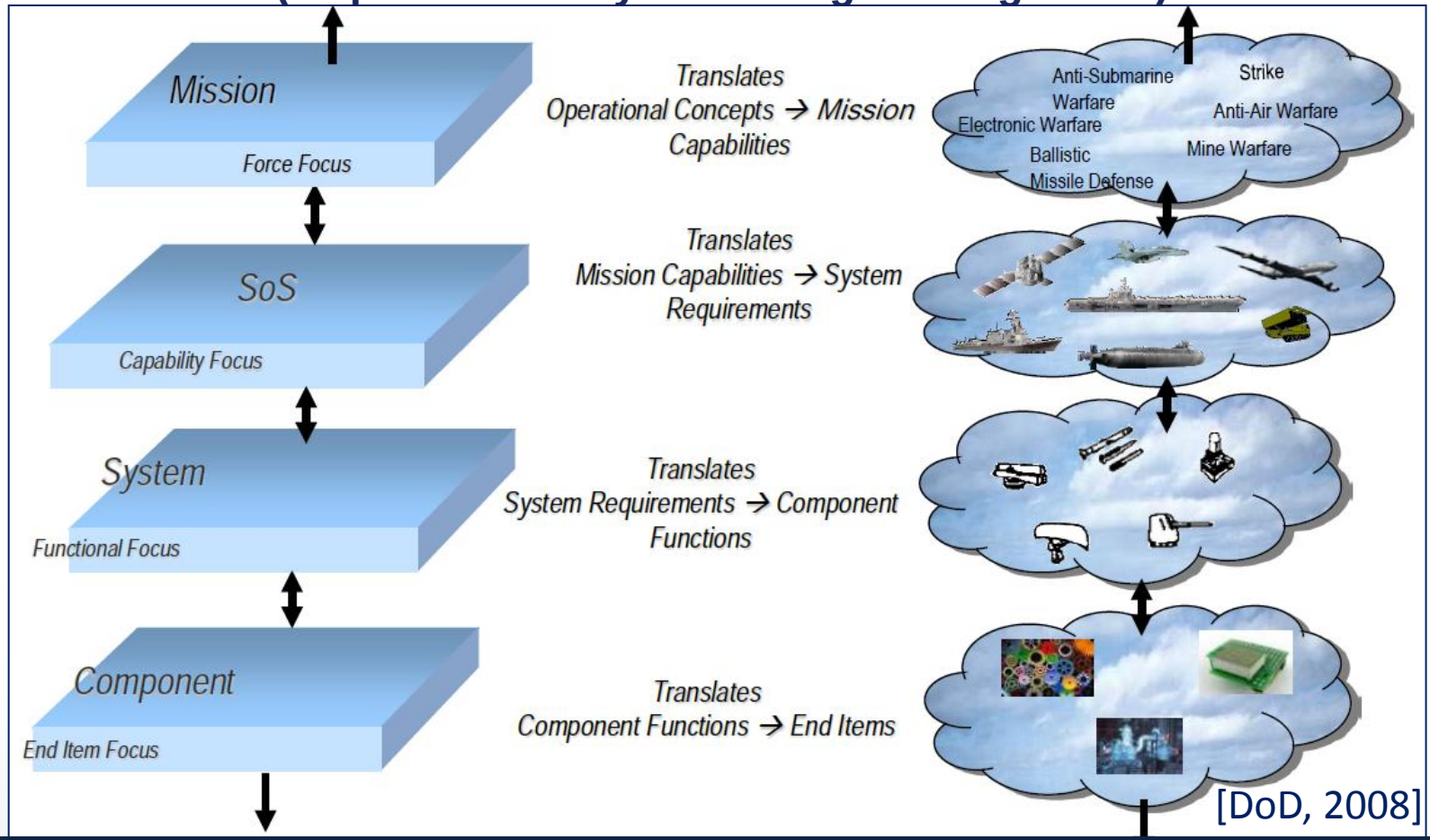



TBMCS CONOPS

**These systems, whether unmanned or not, are bringing more information and decision making requirements to the operator**

# Department of the Navy Engineering of Systems

## (a spectrum of Systems Engineering levels)

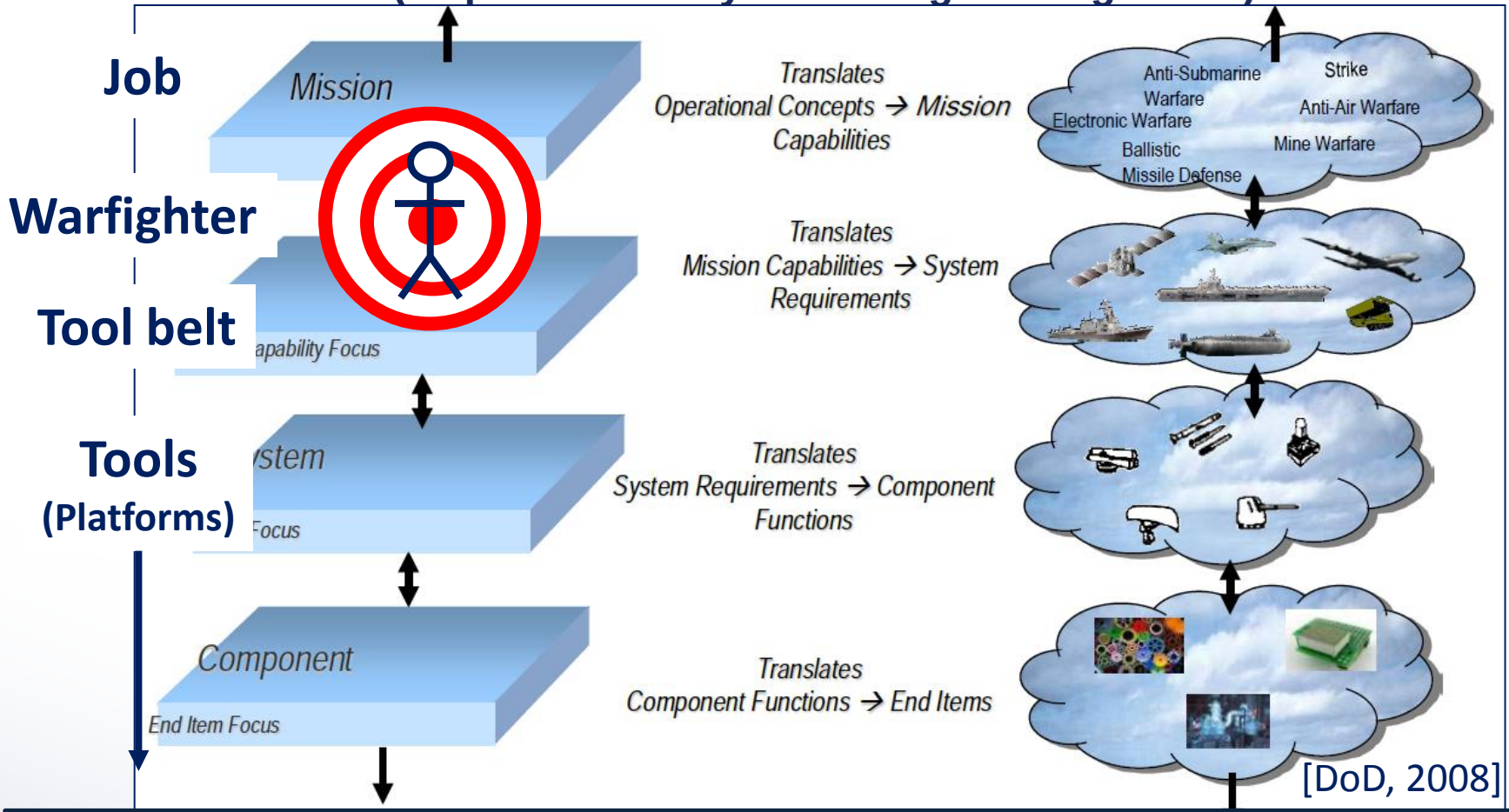



[DoD, 2008]

**Capturing capability level performance of the warfighter / decision maker is a necessary precursor to decomposing and communicating 'requirements' across these strata**

# Department of the Navy Engineering of Systems

## (a spectrum of Systems Engineering levels)




[DoD, 2008]

**Capturing capability level performance of the warfighter / decision maker is a necessary precursor to decomposing and communicating 'requirements' across these strata**

# Advanced Warfighting Capabilities

- Products of innovation necessitate development of new employment concepts / tactics
  - Developmental mission-based environment (e.g. OITL)
- New approaches to assessing performance (MOPs) and effectiveness (MOEs) at the capability (i.e. SoS) level
- Operator integration dimension
  - Learning / Training
  - Usability / Effectiveness

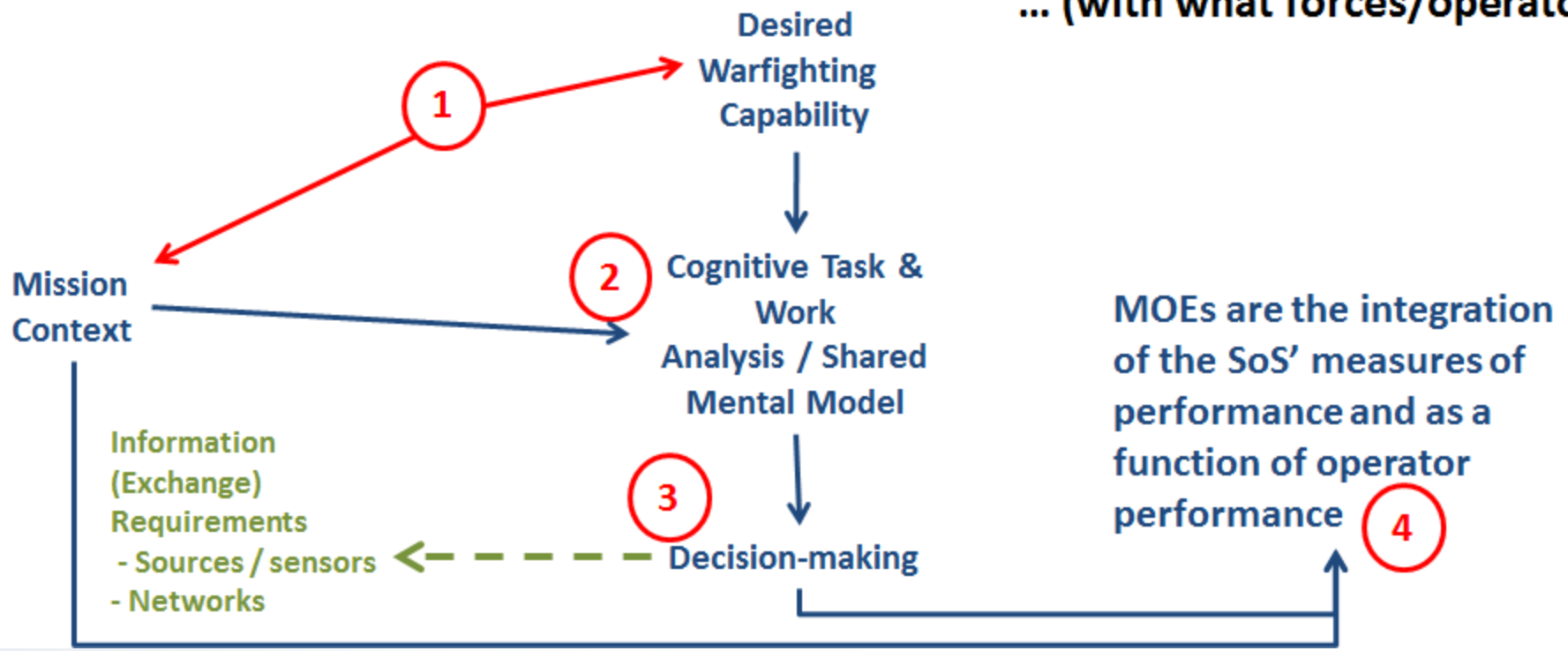
**New capabilities metrics are needed to effectively inform decision makers**

# SoS Level Requirements: Integration of individual systems (hardware, software, operators) with aggregated warfighters as force multiplier

**The integration of 1-3 – "we need to be able to … (what?)"**

**Therefore, 4 – " …and we need to be able to do it … (how fast/easy);**

**… (with what forces/operators?)**




**Contributions of all constituent systems with human operator performance as the unifying attribute**

# HSI Mandate and SoS SE Opportunity

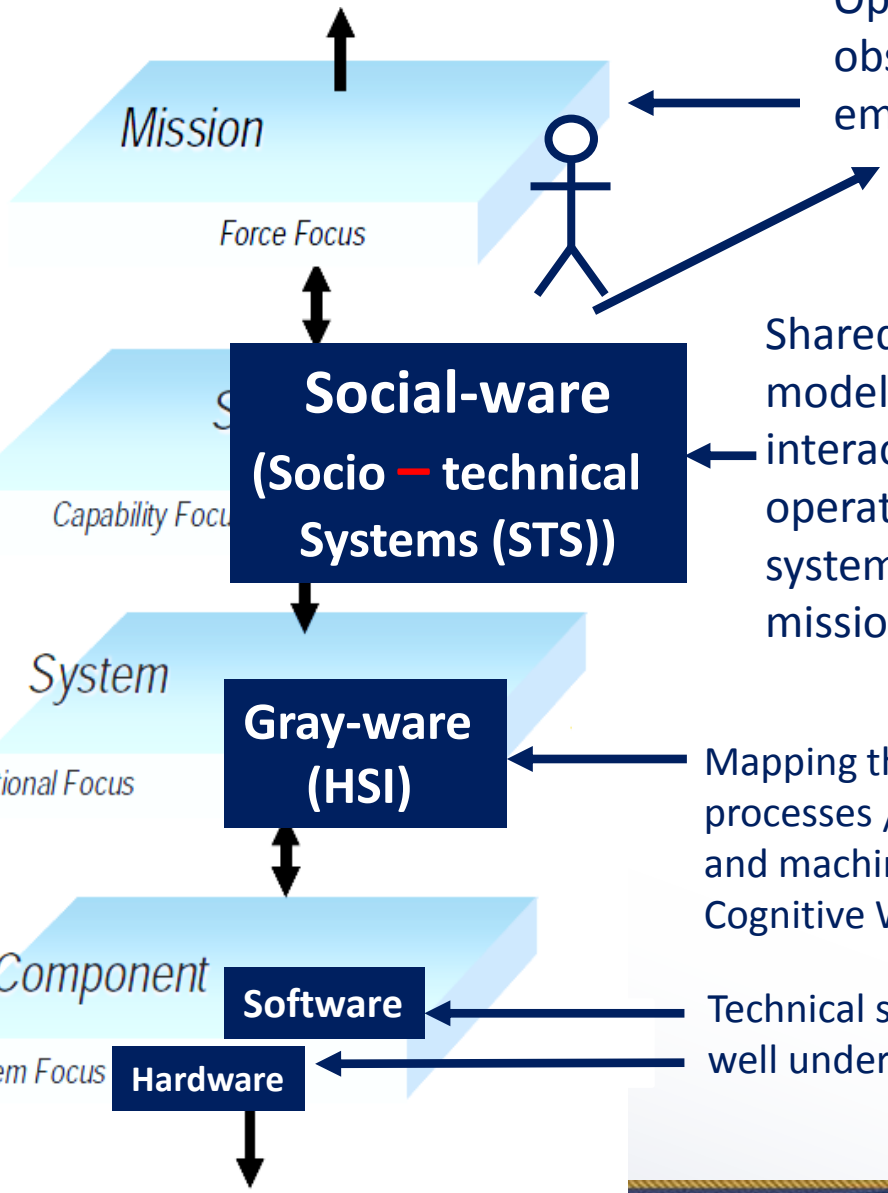
- DoD Instruction 5000.2 requires an acquisition program manager to initiate a Human Systems Integration program in order to:
  - Optimize total system performance
  - Minimize total ownership costs, and
  - Ensure the system built accommodates user characteristics to operate, maintain, and support the system

- Systems Engineering (SE) Guide for Systems of Systems focuses on next level (SoS) human/operator/warfighter interactions across a mission capability
  - Considerations in creating a new capability from existing systems:
    - Human interface variations in and among individual systems
    - Usability / training-required skill sets / personnel requirements
    - Beneficial unintended consequences

- SoS SE must balance SoS needs with individual system needs [DoD, 2008]

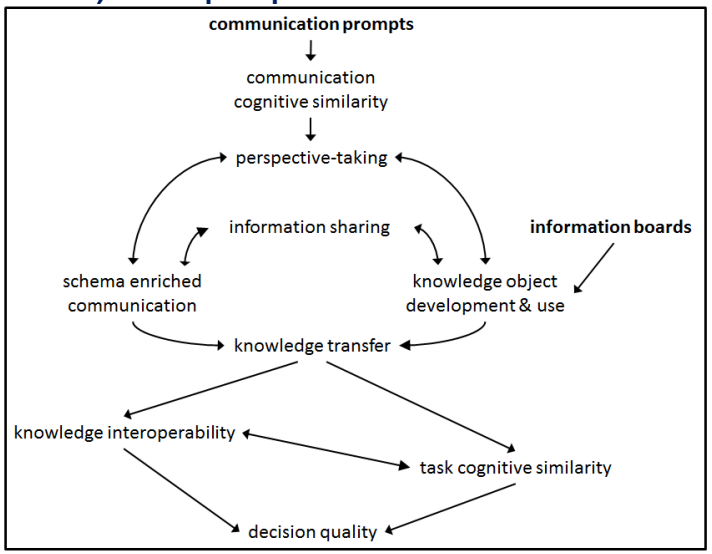
**SoS SE/design to incorporate warfighter performance at the capability (SoS) level to an effectiveness metric**

# Requirements Evolution




Operator in the Loop events - "test-bed" / observation window into SoS development, emergent behaviors, and properties

Shared mental model-social interaction of operators and systems achieving mission success



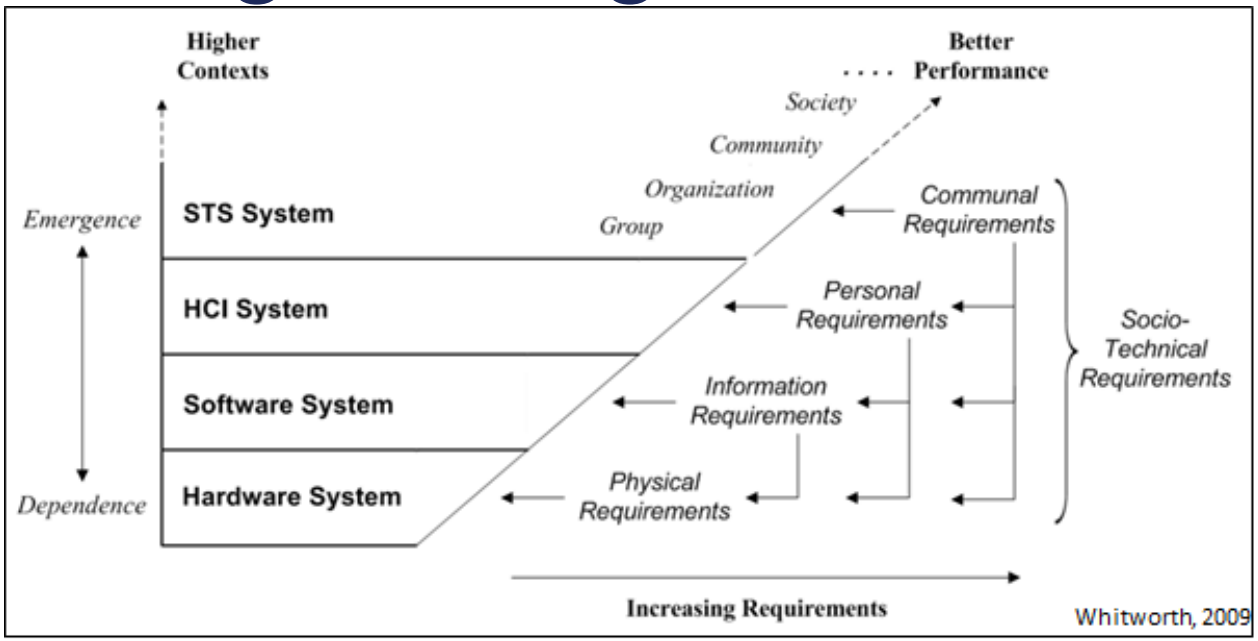

Components and cognitive processes of the C-MAP

Collaboration and Meaning Analysis Process (C-MAP) Rentsch - 2010

Mapping the operators' decision-making processes /interaction between operator and machine – Cognitive Task Analysis / Cognitive Work Analysis

Technical specifications well understood / documented / practiced

# Hybridizing Cognitive & SoS Engineering Tenets




**IT STS Communal Requirements**

- Synergy
- Openness
- Transparency
- Freedom
- Morale
- Privacy
- Identity
- Order

Social Requirements of Technical Systems - Whitworth, 2009

**STS Design Principles**

- Compatibility
- Minimal Critical Specification
- Variance Control
- Boundary Location
- Information Flow
- Power and Authority
- Multifunctional Principle
- Support Congruence
- Transitional Organization
- Incompletion

Army-Centric SoS Analysis Definition-Smith et al 2011

**Macrocognitive Metrics Goals**

- Creativity
- Real-time
- Objective
- Unobtrusive
- Diagnostic

Potential Discriminating Metrics of Cognitive Task Performance in Mission Command - Acchione-Noel, et.al., TRADOC Analysis Center, 2010

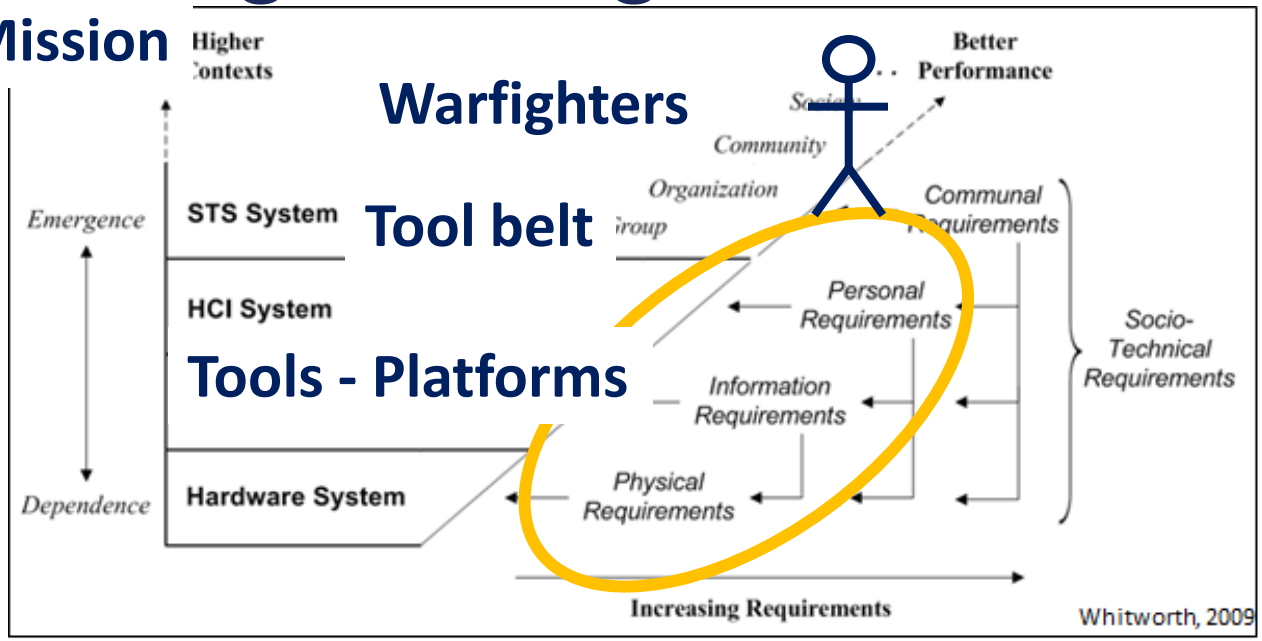
**Supervisory Control Metric Evaluation Criteria**

- Comprehensive understanding
- Experimental constraints
- Statistical efficiency
- Measurement technique efficiency
- Construct validity

Metrics for Supervisory Control System Evaluation-Cummings, 2013

# Hybridizing Cognitive & SoS Engineering Tenets

**Mission**




**IT STS Communal Requirements**

- Synergy
- Openness
- Transparency
- Freedom
- Morale
- Privacy
- Identity
- Order

Social Requirements of Technical Systems - Whitworth, 2009

**STS Design Principles**

- Compatibility
- Minimal Critical Specification
- Variance Control
- Boundary Location
- Information Flow
- Power and Authority
- Multifunctional Principle
- Support Congruence
- Transitional Organization
- Incompletion

Army-Centric SoS Analysis Definition-Smith et al 2011

**Macrocognitive Metrics Goals**

- Creativity
- Real-time
- Objective
- Unobtrusive
- Diagnostic

Potential Discriminating Metrics of Cognitive Task Performance in Mission Command - Acchione-Noel, et.al., TRADOC Analysis Center, 2010

**Supervisory Control Metric Evaluation Criteria**

- Comprehensive understanding
- Experimental constraints
- Statistical efficiency
- Measurement technique efficiency
- Construct validity

Metrics for Supervisory Control System Evaluation-Cummings, 2013

# Getting to Warfighting Metrics

## Adapted Metric Classes

- Mission effectiveness

Component systems' performance

  - Usability, adequacy, reliability
- Human behavior
  - Attention allocation
  - Information processing efficiency
    - Recognition efficiency
    - Decision-making efficiency
    - Action implementation efficiency
- Human behavior precursors
  - Cognitive precursors
  - Physiological precursors
- Collaborative metrics
  - Decision maker / Individual Platform collaboration
  - Decision maker / Decision maker
  - Individual Platform / Individual Platform collaboration

Adapted from Metrics for Supervisory Control System Evaluation-Cummings, 2013

## Potential SoS Warfighter Metrics

- Battlespace extension (Space)
  - Capacity
- Survivability (Force)
  - Threat exposure
  - Threat effectiveness
- Engagement efficiency (Force)
  - Improve capability to consistently employ on (or ahead of) desired timeline against a specific target (set / presentation / etc.) using a particular kill-chain and achieving a constant / desired level of effectiveness
- Flexibility (Force, Space, Time)
  - Having more than one option (e.g. multiple candidate kill-chains) for the conduct of an engagement against a given target or target-set can facilitate, or translate into, benefits in one or more of the aforementioned areas.
- Decision-making time (Time)

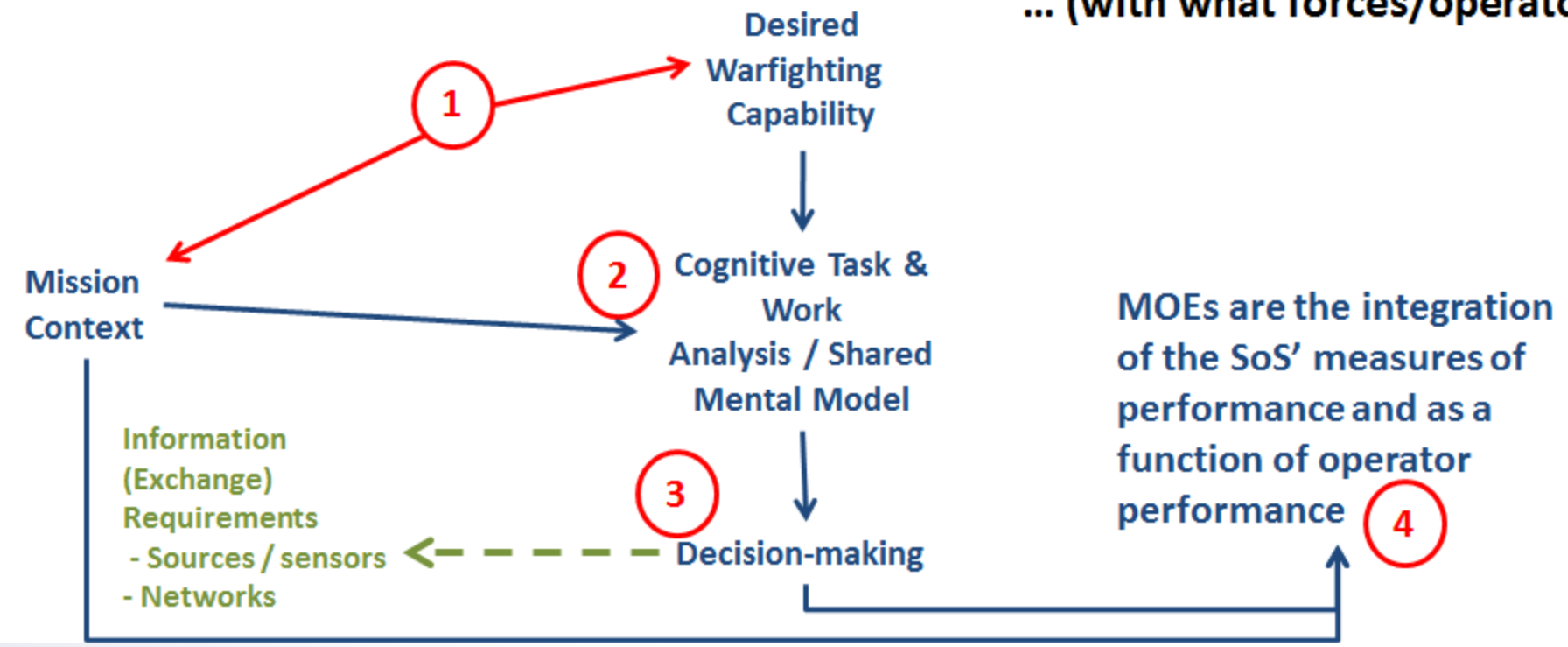
Derived from Herdlick, Johns Hopkins University / Applied Physics Laboratory, Working Papers

# SoS Level Requirements: Integration of individual systems (hardware, software, operators) with aggregated warfighters as force multiplier

**The integration of 1-3 – "we need to be able to … (what?)"**

**Therefore, 4 – " …and we need to be able to do it … (how fast/easy);**

**… (with what forces/operators?)**




**Contributions of all constituent systems with human operator performance as the unifying attribute**

# Leverage OITL Capabilities

- Promoted use – developers, testers and **USERs**
  - Private companies (i.e. Boeing, BAE)
  - National Research Council [2006]
  - Navy SYSCOMs collaboration
  - Application / Implementation analysis
    - Unprecedented Systems – Weiss, 2009
    - Military command and control systems – Roodt, 2010
    - Rapid prototyping – Beevis, 1992
  - Training environments (live, virtual, constructive)
- Understand social dependencies of established SoS – emergent properties / capabilities for requirement definition and linkages to military capability factors (force, time, speed)
- Incorporate refined requirements and metrics to improve current SoSs, develop new ones, and as a weighting factor for warfighting capability (hard-ware, soft-ware, gray-ware, social-ware) decisions
- Mixed-fidelity Operator-in-the-Loop Federations-of-Models facilitate development of capability-based designs and new employment concepts
- Establishment of the SoS objective is reached through an iterative process – [Keating, 2008]

**OITL experiments offer opportunities to capture / quantify operators' cognitive requirements in operationally-representative scenarios**

# Change What We Should

- Understand and quantify human performance as the ultimate measure for capability effectiveness in developing system of systems solutions
- Adopt capabilities based approach to requirements development and characterization
- Ensure integration and interoperability initiatives yield capabilities-based systems of systems

**Change paradigms to incorporate and apply capability-centric requirements**

# DISCUSSION

# References


- DoD Guide to SoS SE
- DoD Instruction 5000.2
- Testing of Defense Systems in an Evolutionary Acquisition Environment, National Research Council, 2006
- The System Engineering and Test Approach for Unprecedented Systems – Weiss, 2009
- Modelling as a Tool in the Engineering of Systems of Systems – Roodt, 2010
- Rapid Prototyping and the Human Factors Engineering Process – Beevis & Denis, 1992
- Test as We Fight – O'Donoghue, 2011
- Transferring Meaning and Developing Cognitive Similarity in Decision-making Teams: Collaboration and Meaning Analysis Process – Rentsch, Delise, & Hutchison, 2010 from Macrocognition in Teams: Theories and Methodologies By Michael P. Letskye, ed.
- Social Requirements of Technical Systems - Whitworth, 2009
- Metrics for Supervisory Control System Evaluation - Cummings, 2013 from The Oxford Handbook of Cognitive Engineering, 2013
- Potential Discriminating Metrics of Cognitive Task Performance in Mission Command - Acchione-Noel, Noel & Cox, TRADOC Analysis Center, 2012
- An Army-Centric System of Systems Analysis (SoSA) Definition – Smith et. al. 2011
- Herdlick, Johns Hopkins University / Applied Physics Laboratory, Working Papers, 2013
- System of Systems Engineering Requirements Challenges and Guidelines – Keating, 2008

**CDR Justin Shoger, USN**

PMA205, Aviation Training Systems

– Live, Virtual, Constructive Architectures Lead

Naval Air Systems Command

NAS Patuxent River, MD

(301) 757-8149

Justin.l.shoger@navy.mil