Integrating the Systems Engineering "V" in a Systems of Systems

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Mr. Jack Sheehan (jhs@orsacorp.com)

Dr. Paul H. Deitz (Paul.H.Deitz@us.army.mil)

Dr. David M. Bassan

Bottom Line Up Front

- Employ a Mission-based SE in an SoS environment approach to **complete** the (traditional) Materiel-based SE "V" (SE-V) in the development of DOTMLPF Capabilities for the warfighter.

- Retaining Mission, Task, **and** Human Dimension context throughout the Capability lifecycle provides assessment results
  - in traditional Materiel-base terms **and**
  - their relationships and contributions both direct and indirect to warfighting operational performance and mission effectiveness.

- Mission-based SE in SoS is an **extension** of MBT&E compatible with the
  - OSD/P&R directives for reporting METL-based Readiness
  - Joint GEL directive for certifying deploying units,
  - JCIDS Capability-based Acquisition
  - DoD SE Guide for SoS, and
  - DOT&E JTEM framework and procedures.

METL: Mission-Essential-Task-List with measures, conditions and standards to accomplished a desired end result
SoS: Systems of Systems
SE "V": Top-Down definition and design then Build followed by Bottom-Up integration, and verfication
DOTMLPF: Doctrine, Organization, Materiel, Leadership, Personnel, and Facilities
HD: Army Human Dimension initiative in three behavior domains -- Social, Cognitive, and Physical
MBT&E: ATEC Mission-based Test & Evaluation framework, procedure, and complexity constraint strategies
GEL: Joint Guidance for Employment of Forces for unit certification prior to deployment
P&R: OSD Personnel & Readiness
JTEM: Joint Test & Evaluation Methodology

Definitions (1of 2)

- **System (S)*** - A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements; that group of elements forming a unified whole [JP 1-02 & JP 3-0].
- **Capability*** - is the ability to achieve a desired effect under specified standards and conditions through combinations of ways and means to perform a set of tasks [CJCS, 2007(2)].
- **Family of Systems (FoS)*** - a set of systems that provide similar capabilities through different approaches to achieve similar or complementary effects [CJCS, 2007(1)].
- **System of Systems (SoS)*** - is defined as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities [DoD, 2004(1)].

* Taken from the DoD SE Guide for SoS

Definitions (2 of 2)

- **Virtual SoS*** – Group lacks a central management authority and a centrally agreed upon purpose for the system-of-systems.
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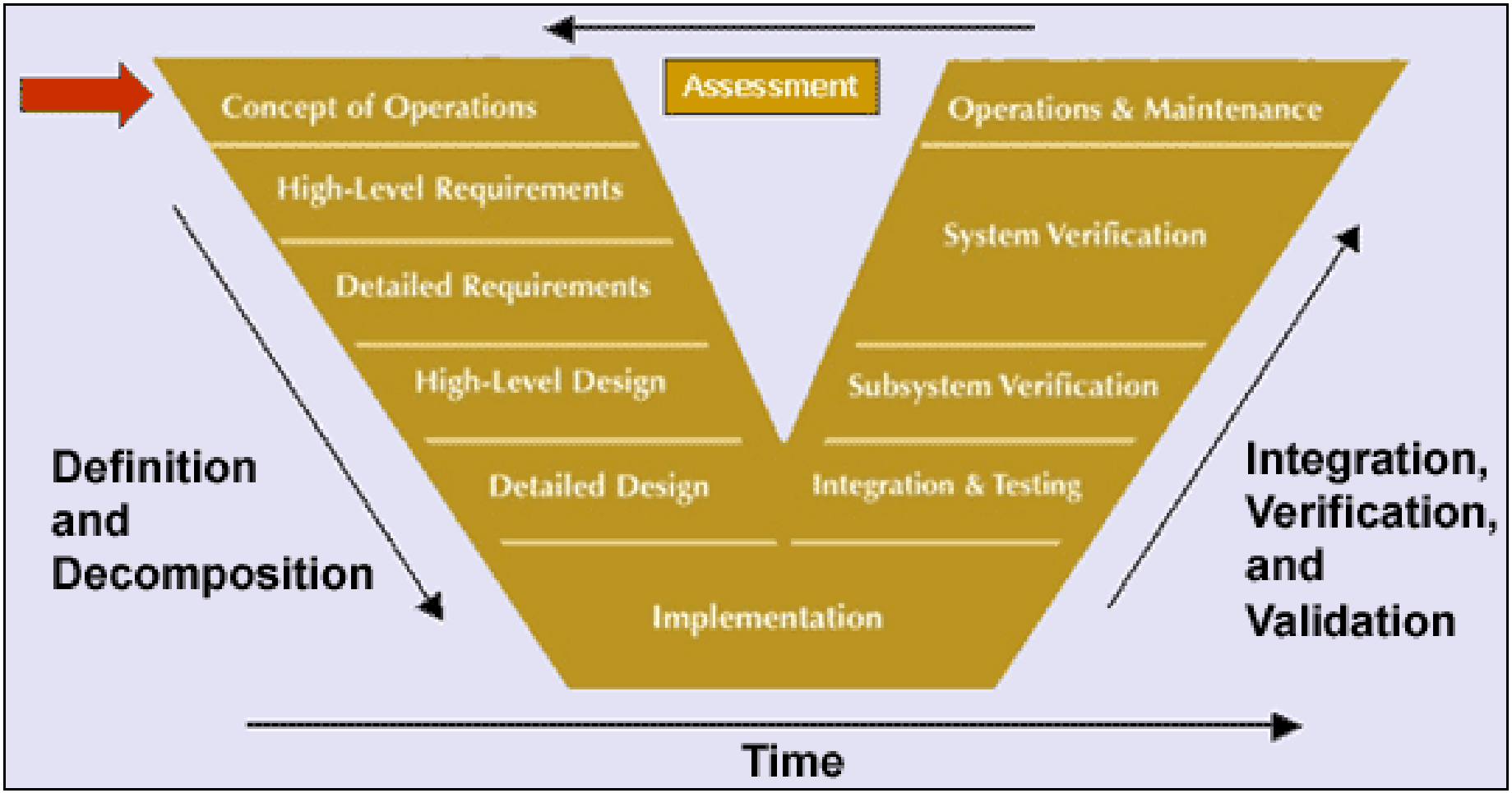
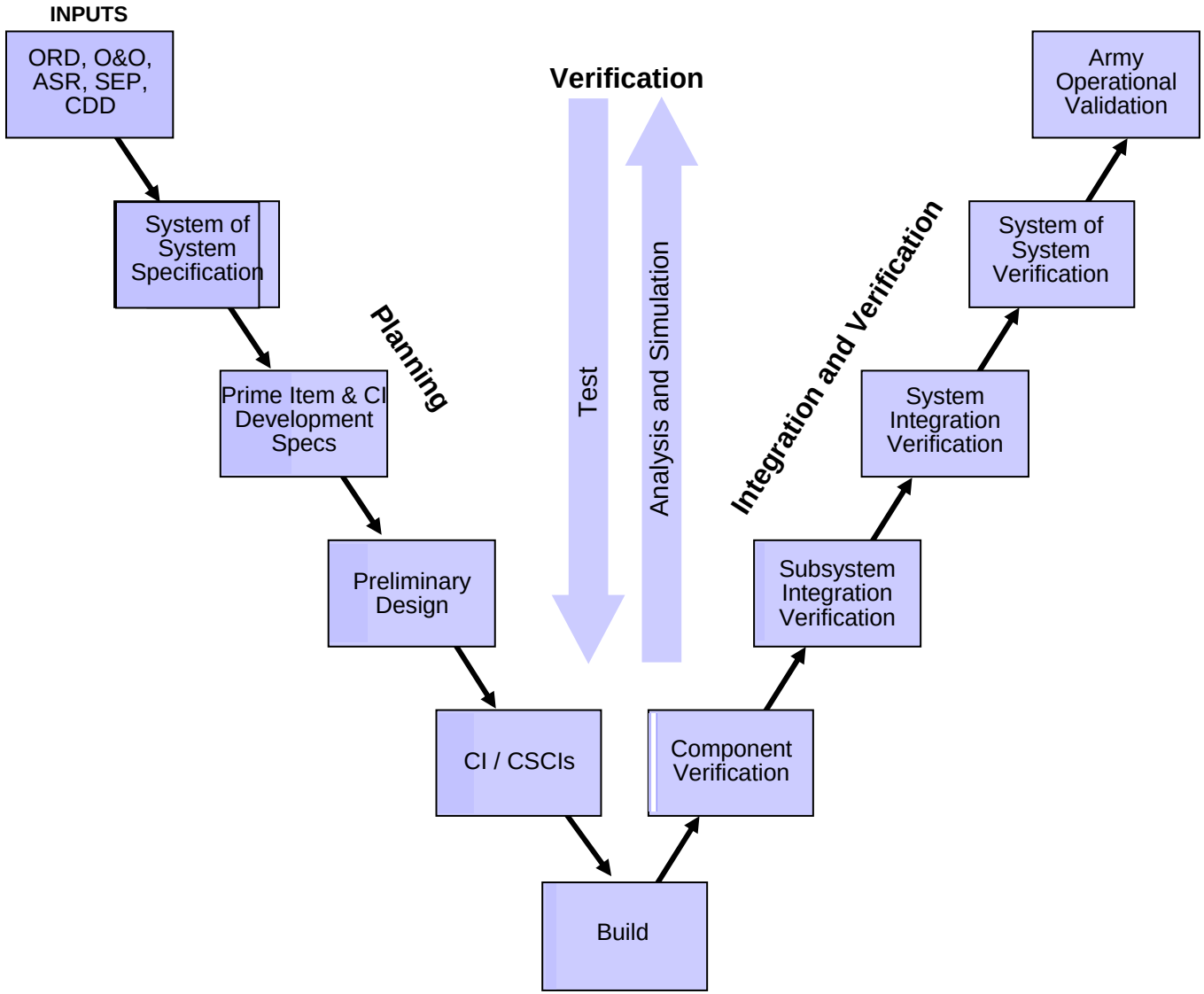
- **Acknowledged SoS*** – Group has recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches. Changes in the systems are based on collaboration between the SoS and the systems.
- **Directed SoS*** - The group, an integrated system-of-systems, is built and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes as well as any new ones the system owners might wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose.

* Taken from the DoD SE Guide for SoS

Systems Engineering "V" (1of 3)

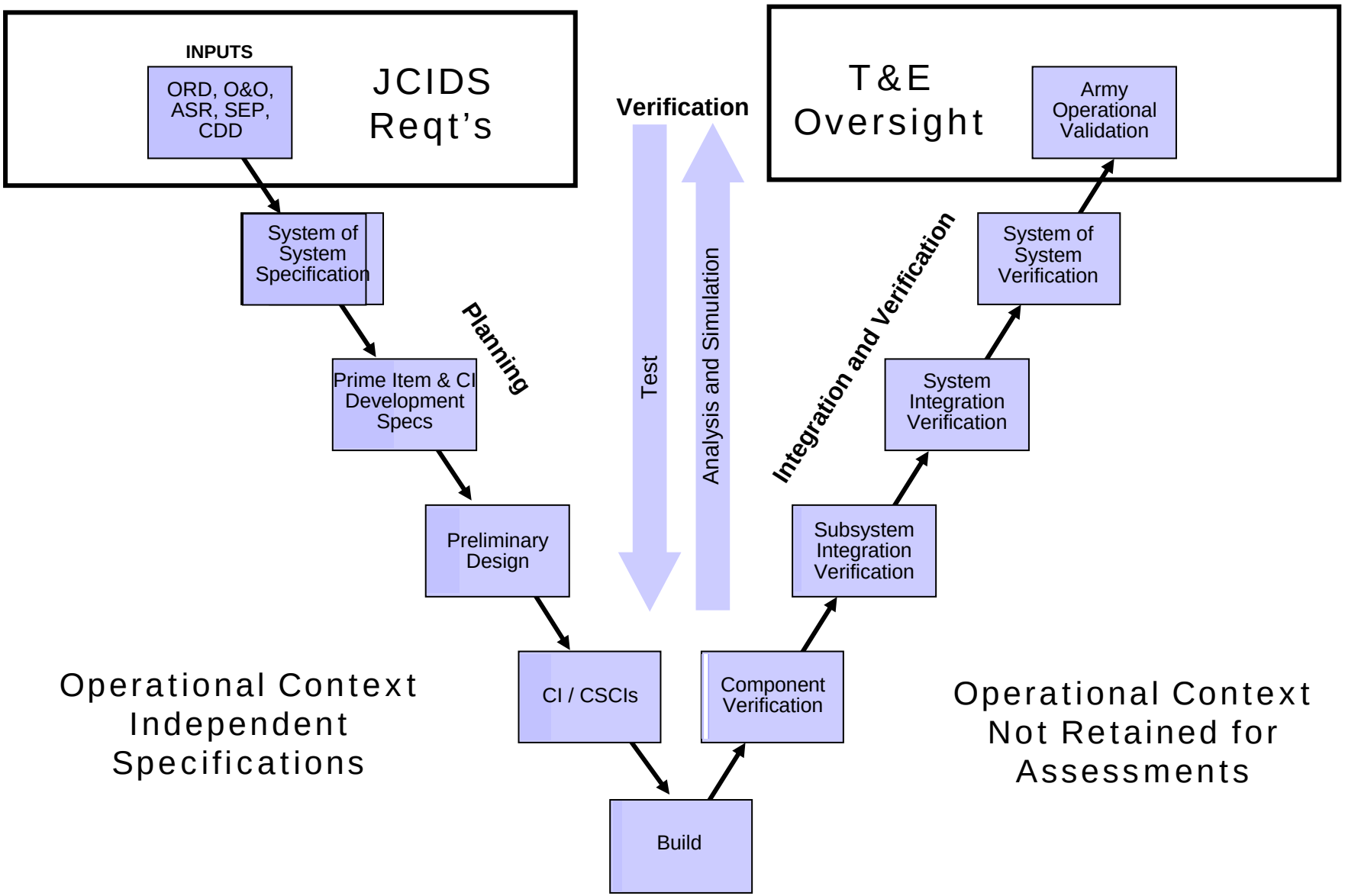


Systems of System Engineering (2 of 3)



Taken from 21 Jun2 20005 FCS Review to DAB

SE in SoS Environment Issues (3 of 3)

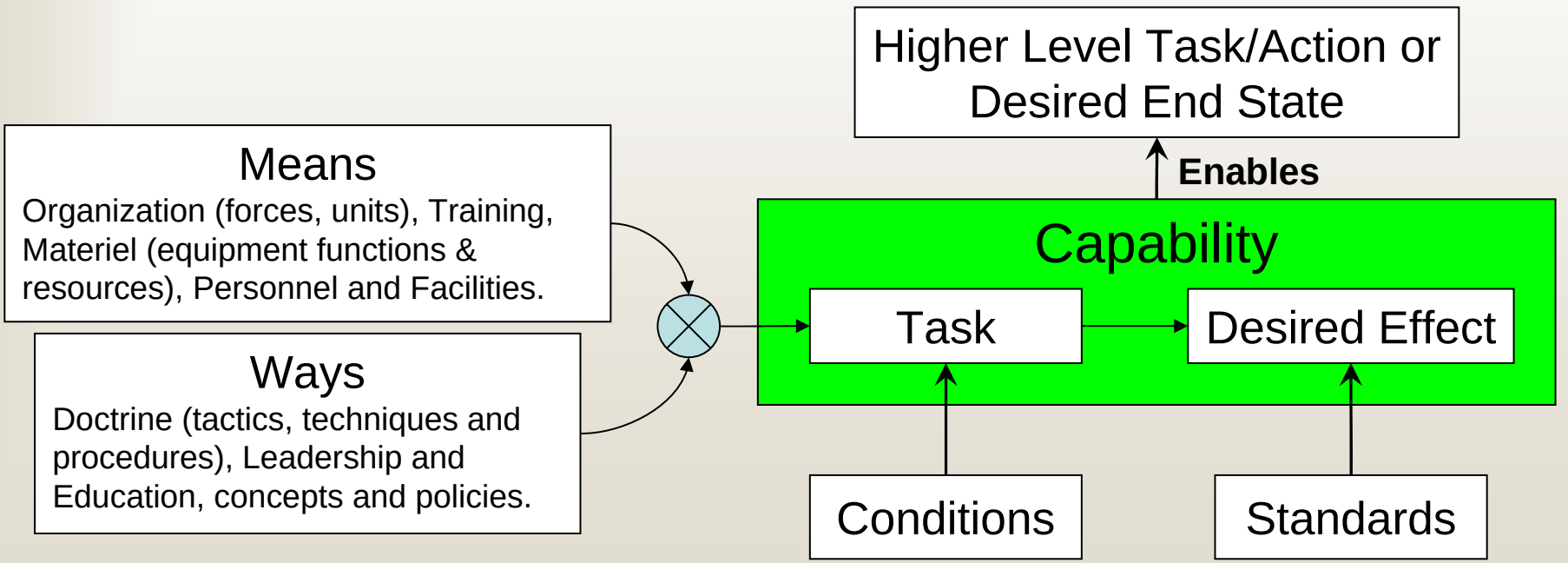


Taken from 21 Jun2 20005 FCS Review to DAB

MBT&E Building Block

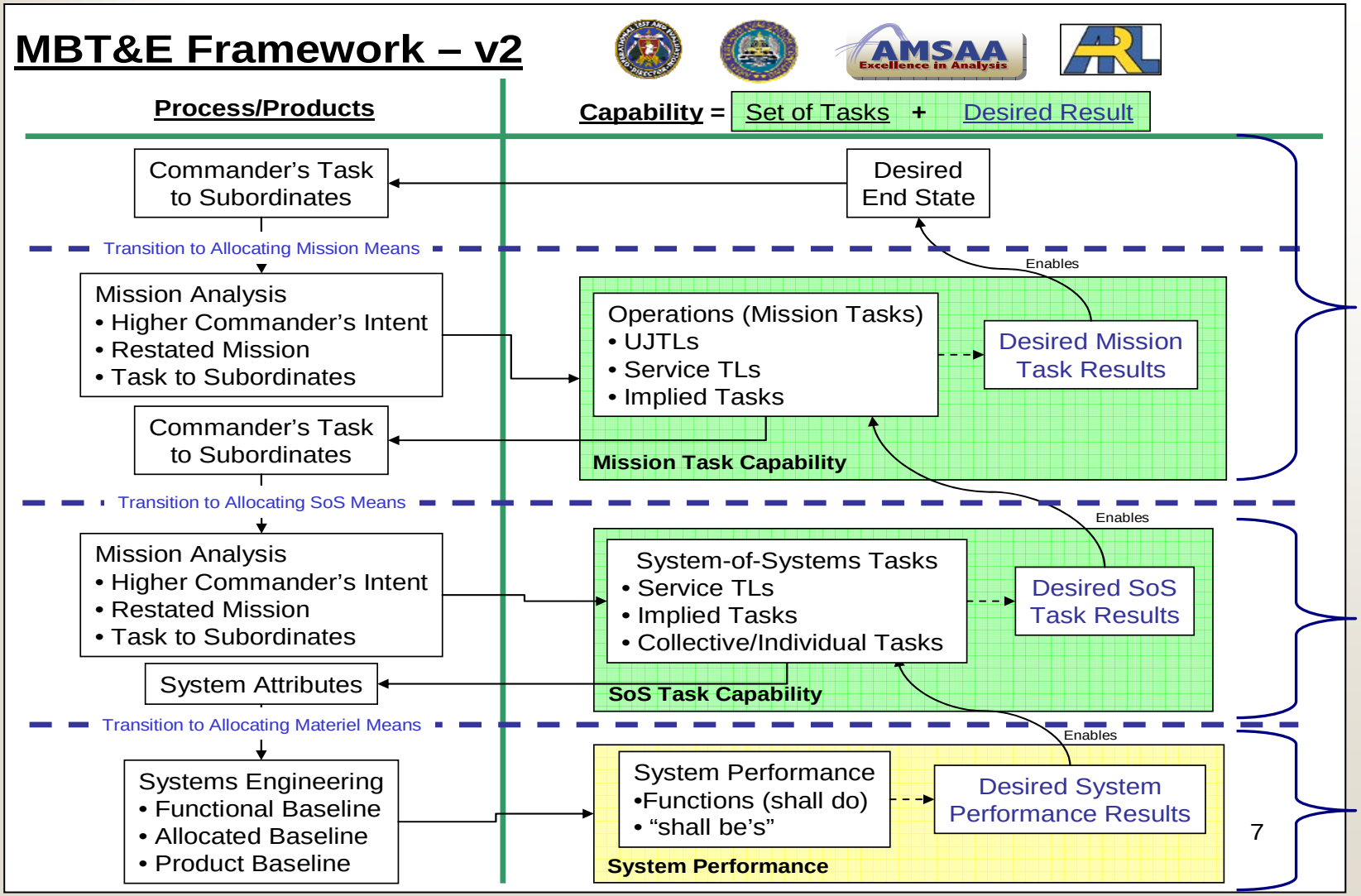
Capability[1] – The ability to achieve a **desired effect** [or result, outcome, or consequence of a task[2]] …

- under specified **standards and conditions**
- through a combination of **means and ways**
- to perform a set of tasks.

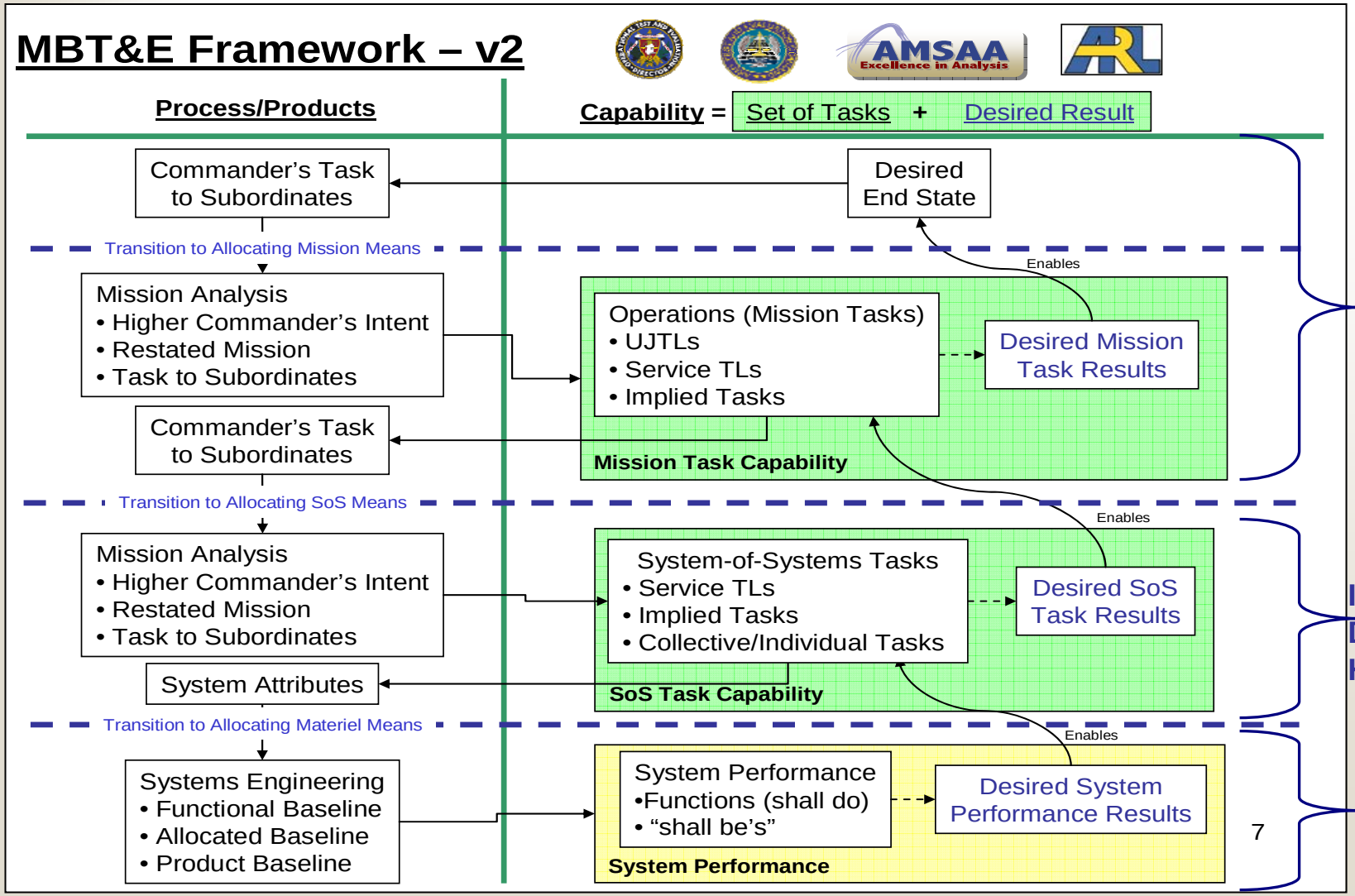


1. CJCSI 3170.01F, May 2007
2. Taken from JP 1-02, Mar 2007, definition of effect.

MBT&E - Task Hierarchy

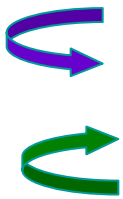


MBT&E - Task Hierarchy



Compatibility

- **ATEC Mission Based Test & Evaluation is consistent with**
  - OSD P&R directives for reporting METL-based Readiness
  - Joint GEF certification for Deployment of Operational Forces
  - JCIDS Capability based Acquisition
  - DoD Systems Engineering guide for Systems of Systems (SE for SoS)
  - DOT&E Joint Test & Evaluation Methodology (JTEM)



Based on Generic, General Purpose Measures/Conditions/Standards

– TPFData List	TO&E (standing)	C-METL	OSD P&R Readiness
– TPFDeploment Data	MTOF (transient)	D-METL	Joint GEF Certification

Based on Mission, Situation Specific Measures/Conditions/Standards

TPFDL: Time Phased Force Data List for deployment planning
TPFDD: Time Phased Force Deployment Data for deployment execution
TO&E: Table of Organization and Equipment for a standing unit
MTOF: Mission Task Organized Force (modeling & simulation term)
C-METL: Core METL defined by Army Force Generation (ARFORGEN) for commonality between units of the same type
D-METL: Directed METL defined by Army Force Generation (ARFORGEN) for a unit with specific deployment orders
GEL: Joint Guidance for Employment of Forces for unit certification prior to deployment
P&R: OSD Personnel & Readiness directives for METL-based readiness reporting
JCIDS: Joint Capability Integrated Development System

MBT&E Procedure

- 19 steps divided into 5 major purpose areas.
  - 1 Pre-step to collect information.

PLANNING

UNDERSTAND THE MISSION	• 4 steps to understand the military operations, tasks, task capabilities and mission context.
UNDERSTAND THE SYSTEM	• 2 steps to understand the components and attributes of the materiel system-of-systems.
	• 1 additional step to understand the mission and system linkages.
DESIGN THE T&E	• 7 steps to design the T&E given the mission and system understanding.

EXECUTING & REPORTING

DETERMINE THE RESULTS	• 3 steps to generate, collect, analyze, and evaluate the data.
REPORT THE RESULTS	• 1 step to format and report the results.

Adaptation to Complete SE-V

- N steps divided into 5 major purpose areas.
  - 1 Pre-step to collect information.

PLANNING

UNDERSTAND THE MISSION	• 4 steps to understand the military operations, tasks, task capabilities and mission context.
UNDERSTAND THE SPEC's	• 2 steps to understand the Context-Independent specifications of the of the materiel system-of-systems.

- 1 additional step to understand the mission and system specifications linkage (retain Context-Dependence link).

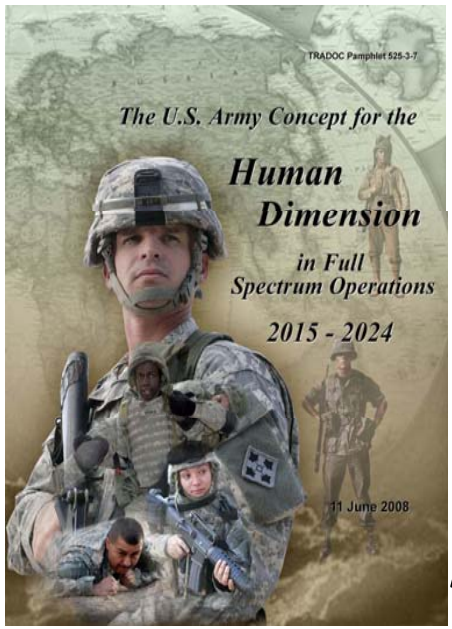
SE

DESIGN THE System	• SE steps to design the system to the specifications given the Mission, Task, HD context understanding.

EXECUTING & REPORTING

DETERMINE THE RESULTS	• 3 steps to generate, collect, analyze, and evaluate the data.
REPORT THE RESULTS	• 1 step to format and report the results.

If Human Dimension (HD) is the "System"



Human Dimension is parsed by three behavioral domains: Social, Cognitive, and Physical

Social Behavior (9)

- Affects, Emotions, and Moods
- Cultural Awareness (CA) & CA Training
- Ethics & Values / Morals & Beliefs
- Group Dynamics / Group Interactions
- Interpersonal Relations
- Leadership & Leadership Training
- Networking
- Personnel Issues / Recruitment & Retention
- Quality of Life

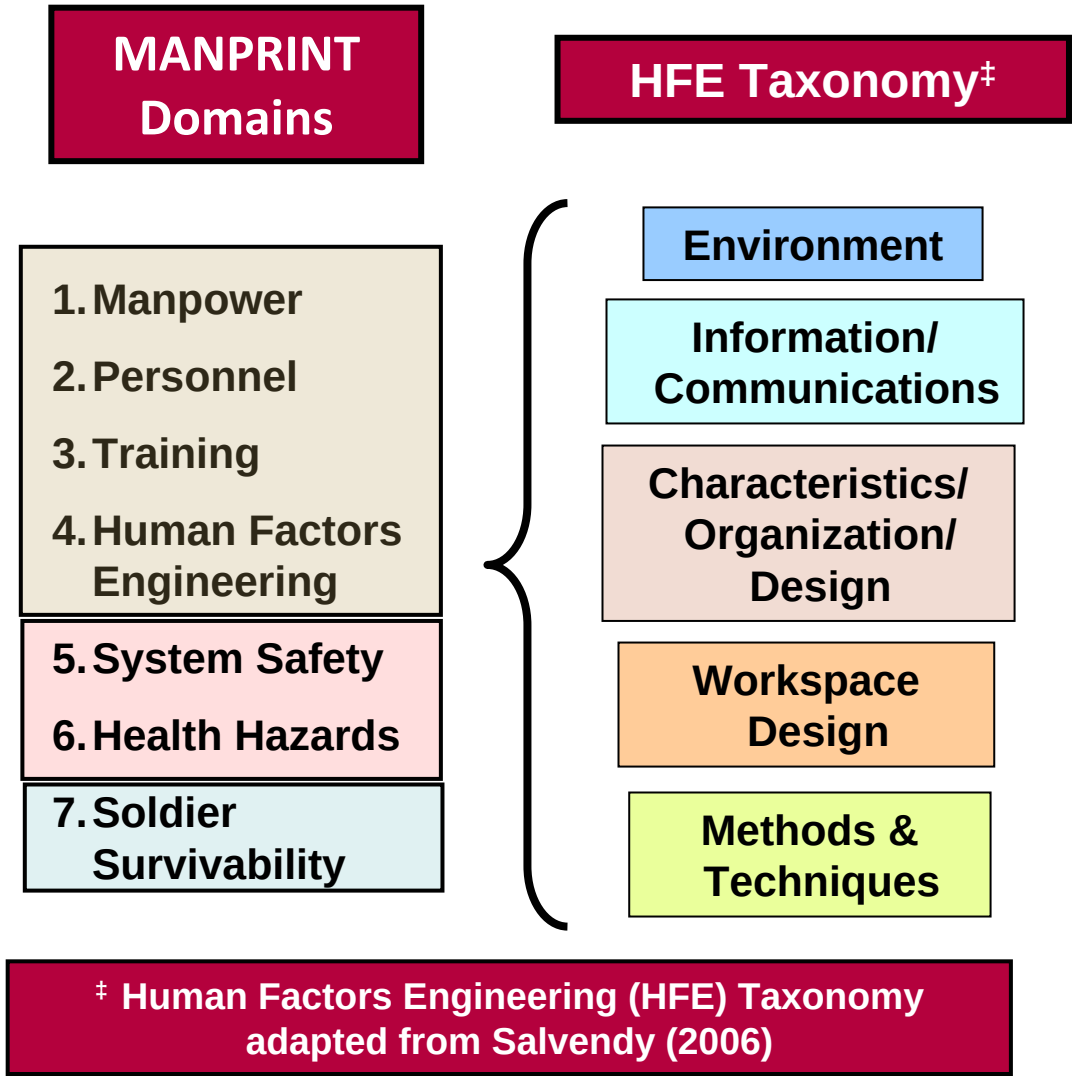
Cognitive Behavior (12)

- Attention & Memory
- Cognitive Workload
- Comprehension / Understanding
- Creativity & Imagination
- Decision Making
- Learning
- Motivation
- Pattern Recognition
- Perception
- Problem Solving
- Projection & Planning
- Situation Awareness

Physical Behavior (13)

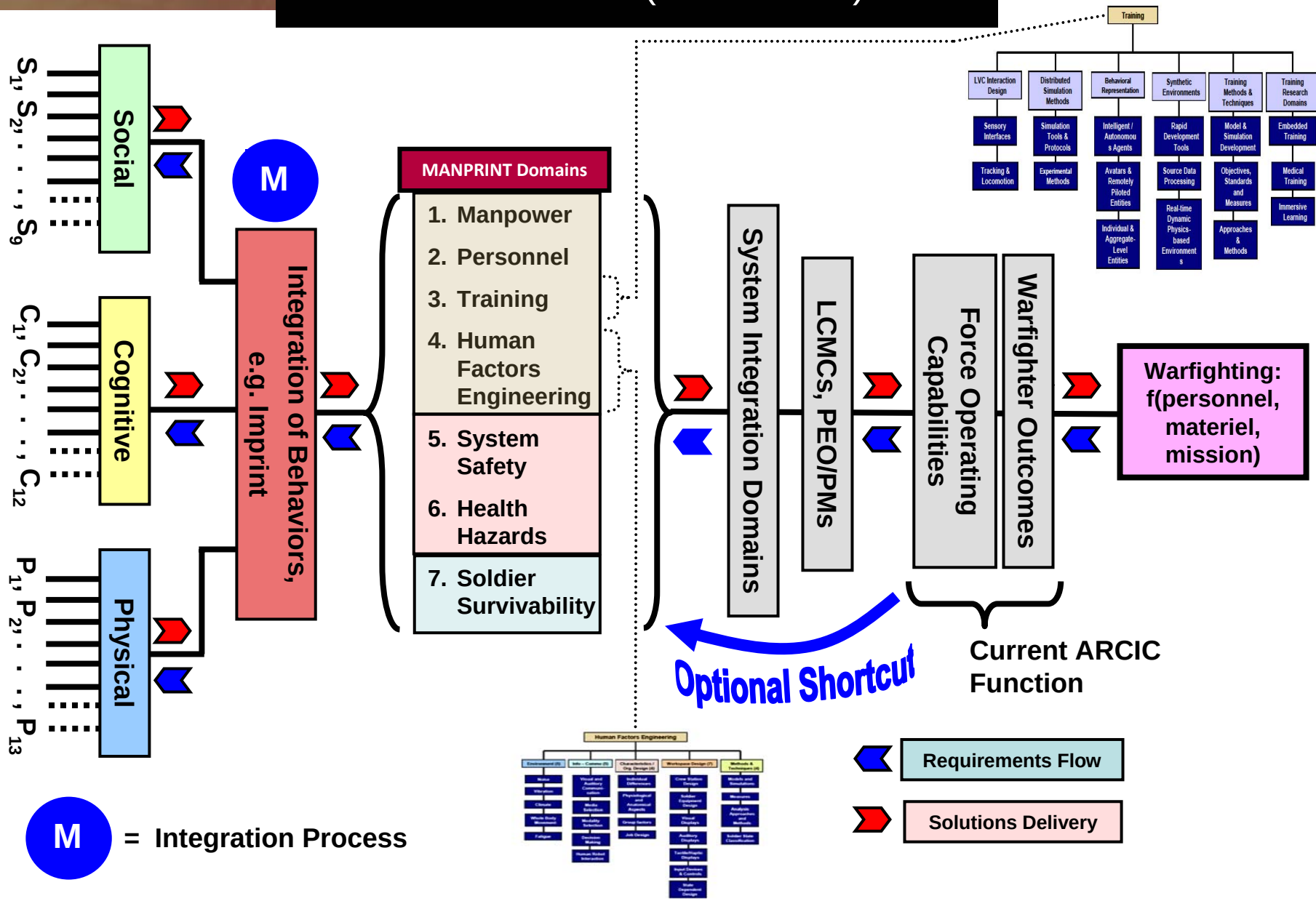
- Anthropometry
- Biological/Physiological Mechanisms
- Biomechanics
- Endurance & Tolerance
- Fitness & Strength
- Health Protection / Preventive Medicine
- Medical Intervention
- Mobility & Dexterity / Movement
- Nutrition
- Physical Adaptability / Survivability
- Physical Comfort
- Sensing
- Task Execution /Action & Reaction

MANPRINT Domains



‡ Human Factors Engineering (HFE) Taxonomy adapted from Salvendy (2006)

Current: Warfighter to Human Dimension (and back)



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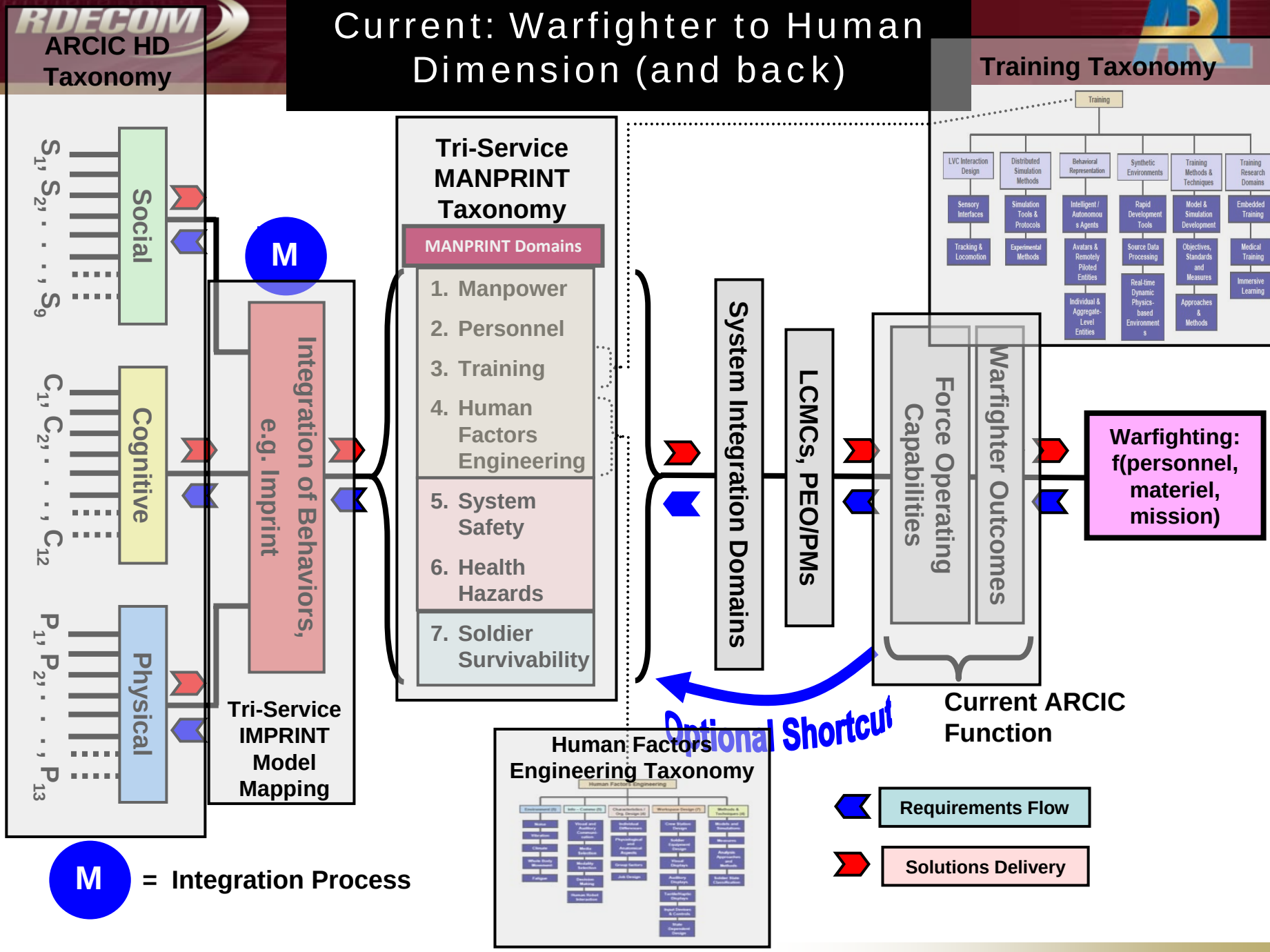
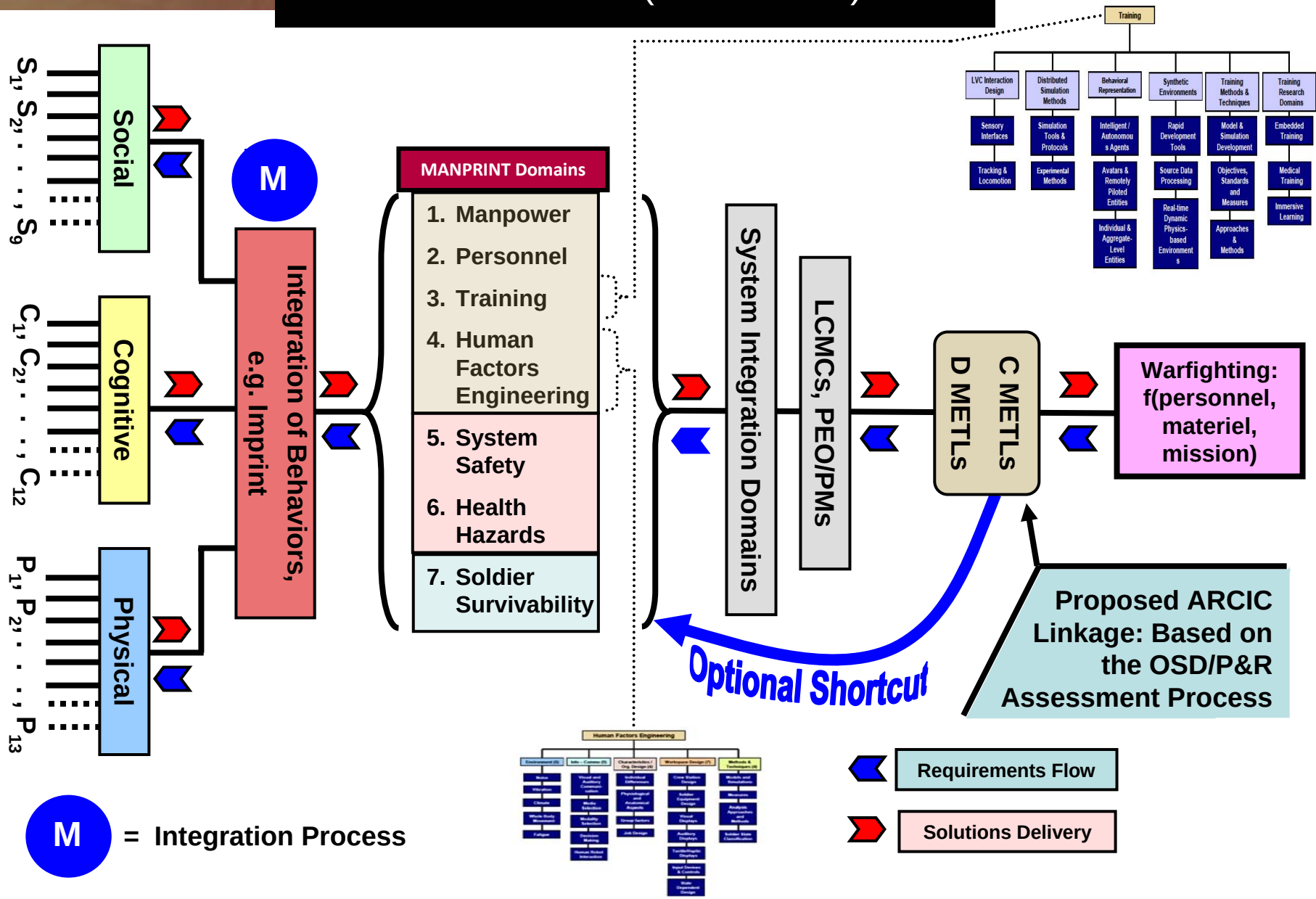
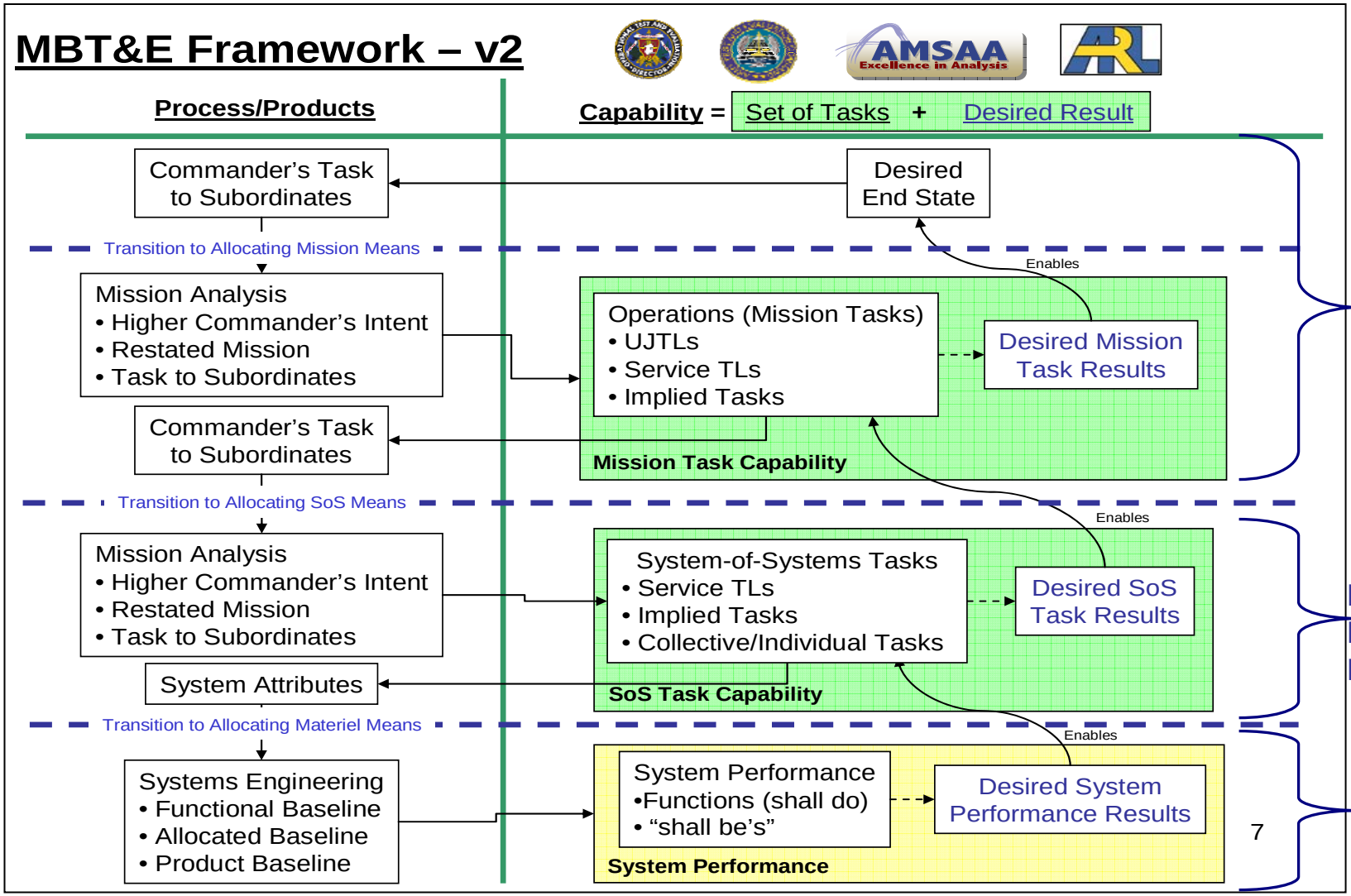


Alternate: Warfighter to Human Dimension (and back)



MBT&E Framework – v2



Benefits

Mission-base SE in an SoS Environment enables identification, trade-off, and design of System structure and allocation, characteristics and performance to:

- Prioritize by stressor relevance to End-Results, Mission-Task effectiveness, SoS-Task performance, Human Dimension, and Operational Variables **as well as** stressor relevance to traditional Materiel and Technology considerations.
- Articulate the impact of System capabilities in **the language of** the warfighter as expressed in the originating JCIDS FAA, FNA, and FSA

FAA: Functional Area Analysis
FNA: Functional Needs Analysis
FSA: Functional Solution Analysis

Summary

- For identified gaps in required Capability, employ a Mission-Essential-Task-List (METL, with measure, conditions and standards) centric Systems-of-Systems (SoS) approach to complete the (traditional) materiel centric Systems Engineering “V” (SE-V) in the conception, development, evaluation, and fielding of DOTMLPF (Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities) solutions for the warfighter

- The key is systematically deriving, retaining, and employing Mission, Task, **and** Human Dimension context throughout the extended SE-V in the SoS environment to need analysis, trade study, design allocation, and capability assessment results in traditional materiel centric terms **and** their relationships and contributions both direct and indirectly to the impact on warfighting operational performance and mission effectiveness.

- This approach is an application of the Missions and Means Framework (MMF) that is tailored to be compatible with the existing Army Guidance for Employment of Forces (GEF) directive for certifying operational forces prior to deployment, the recently released USD/AT&L Systems Engineering Guide for a SoS Environment, and the emerging ATEC Mission-Base Test & Evaluation (MBT&E) and DOT&E Joint Test & Evaluation Methodlodgy (JTEM) a frameworks and procedures. .

Backup

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- **System of Systems (SoS)*** - is defined as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities [DoD, 2004(1)].
- Both individual systems and SoS conform to the accepted definition of a system in that each consists of parts, relationships, and a whole that is greater than the sum of the parts; however, although an SoS is a system, not all systems are SoS. *

* Taken from the DoD SE Guide for SoS

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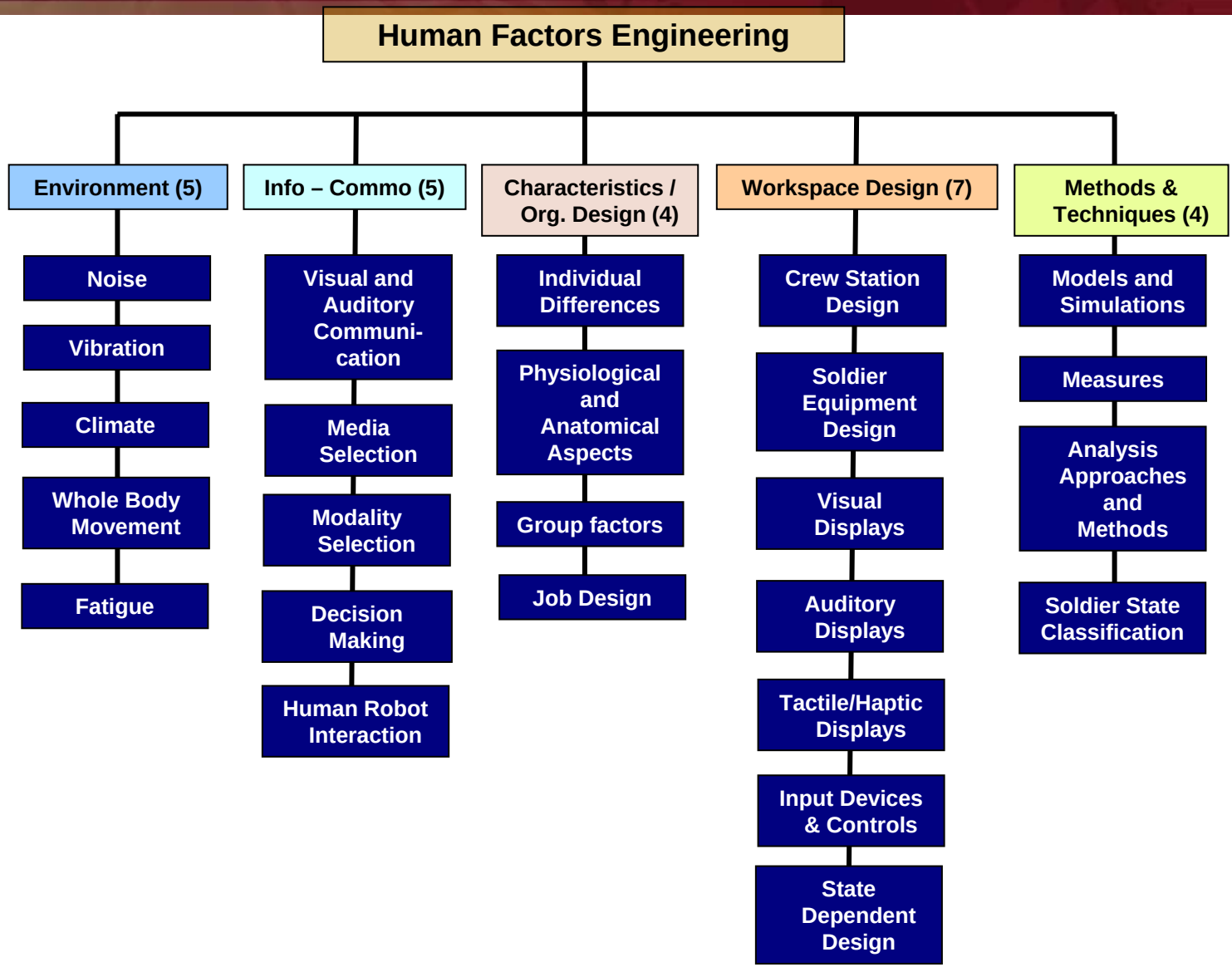
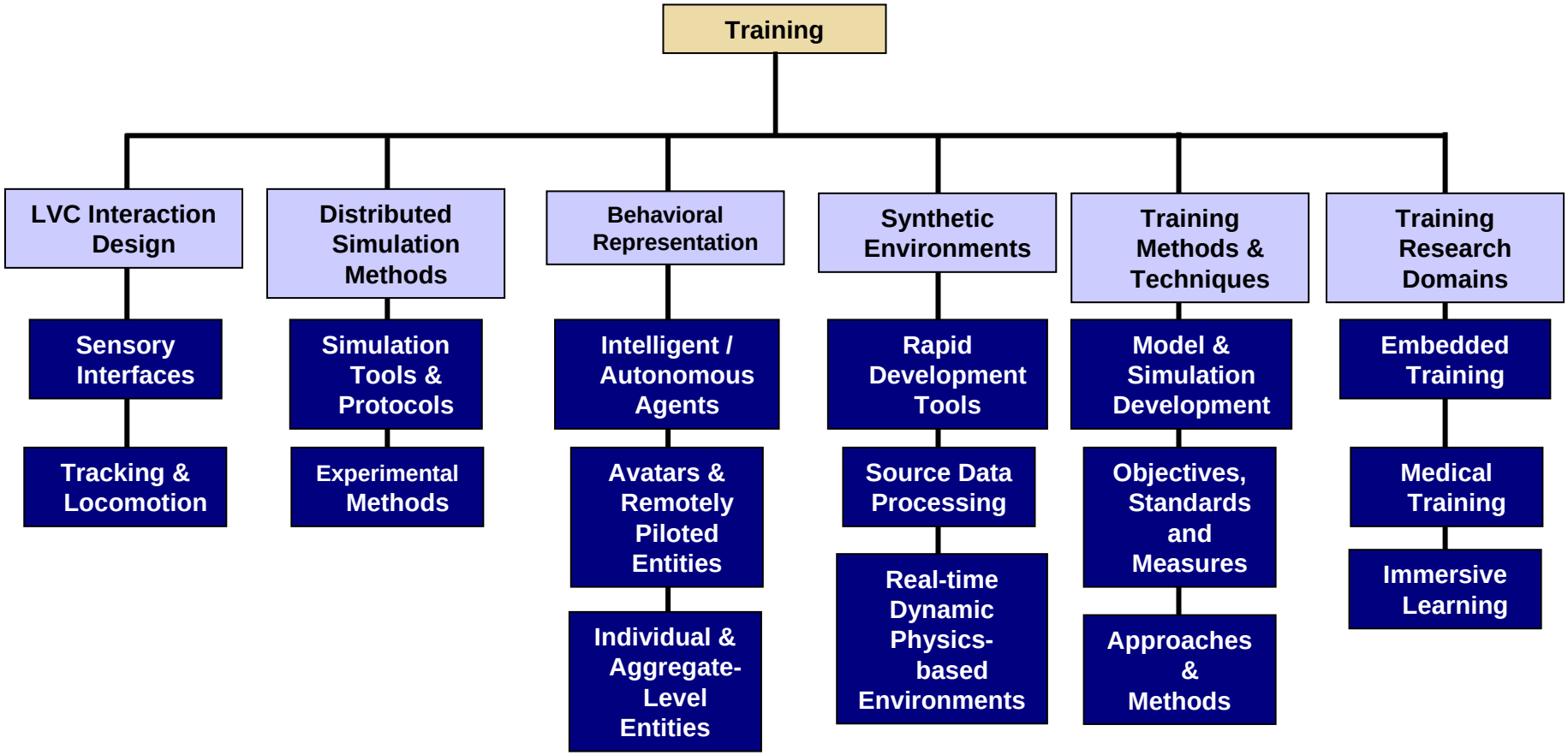
- When a group of systems morphs into an SoS – synergy occurs between the various systems
- When a group of systems is not an SoS – synergy between the various elements does not occur

* Taken from the DoD SE Guide for SoS

Human Factors Engineering Taxonomy




Training
LVC Interaction Design
Sensory Interfaces
Tracking & Locomotion
Distributed Simulation Methods
Simulation Tools & Protocols
Experimental Methods
Behavioral Representation
Intelligent / Autonomous Agents
Avatars & Remotely Piloted Entities
Individual & Aggregate-Level Entities
Synthetic Environments
Rapid Development Tools
Source Data Processing
Real-time Dynamic Physics-based Environments
Training Methods & Techniques
Model & Simulation Development
Objectives, Standards and Measures
Approaches & Methods
Training Research Domains
Embedded Training
Medical Training
Immersive Learning

SoS Elements Crossed with Context Dependency

	Mission	**Doctrine**	**Organization**	**Organization Success Measures**
Context Dependent	Major Combat Ops	Match	Match	Exist
Context Dependent	Stability & Support Ops	Mismatch	Mismatch	Not well developed
Context Independent	Maintain Force	Match	Match	Exist
Context Independent	Establish Cordon	Match	Match	Exist

SoS Forms Crossed with Acquisition Organizational Processes

	System	Directed SoS	Acknowledged SoS	Collaborative SoS	Virtual SoS
Governance	Feudal	Central with limited local autonomy (France, Russia)	Federation with states rights freedom of action (US, Canada)	Tribal	Fair market economy
Conflict Resolution	Adjudicated	Adjudicated	Negotiated	Competed	Pair-wise consent
Schedule	Synchronized	Synchronized	Emergent	Synchronized	Asynchronous

SoS Forms Crossed with Data Management

	System	Directed SoS	Acknowledged SoS	Collaborative SoS	Virtual SoS
Enterprise	No	Yes	Yes	No	No
Communities of interest	Yes, A Priori by design, Stable over whole period	Yes, A Priori by design, evolving, stable when eventually complete	Yes, Evolving during development, then stable when complete	Yes, Evolving during development, then stable when complete	Yes, Morphs as the partners change
local	Yes Abrams	Yes SoSCOE	Yes USMTF/VMF	Yes AKO	Yes Proprietary Protocols

SoS Forms Crossed with Acquisition Life Cycle Management

	System	Directed SoS	Acknowledged SoS	Collaborative SoS	Virtual SoS
Program Risk	Internal	Internal & external	Internal & external	Internal & external	internal
AoA – TRADOC	Early, simple, and complete	Extensive and on-going	Extensive and on-going	Extensive at S level but not at SoS level	Partner selection in business sense
Rqmts - PM	Directed	Directed	Directed	Negotiated	Pair-wise Consent
Trade Studies - PM	Early, simple, and complete	Extensive and on-going	Extensive and on-going	Extensive at S level but not at SoS level	Partner selection in business sense
Build - PM	Well defined prime	Multiple primes & PMs	Multiple primes & PMs	Competitive	By independent partners
Integrate, V&V - PM	Internal to defined prime	Over multiple primes & PMs	Over multiple primes & PMs	Over multiple primes & PMs	Internal to partnership
T&E - ATEC	Independent oversight	Independent oversight	Independent oversight	By developers	By customers