Systems Engineering: Application in complex organizations

Robert Parrish – PEO Simulation, Training, Instrumentation

Kevin Roney – Booz Allen Hamilton

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Introduction

- Systems Engineering evolved because of the complexity in large scale engineering problems, which is a reality of today's projects
- Transformation to Network Centric Operations is another perturbation to the increase in complexity
- Program Executive Office (PEO) is the foundation of DoD material development that produces complex systems and system of systems
- Additionally, the PEO tends to be a complex organization
  - They tend to be large, heterogeneous, exercise control over strategic objectives, and consist of portfolio of projects
  - A PEO is often composed of several Project Managers with their own complex set of systems engineering challenges
- Intuitively, we understand that systems engineering at the Project Manager (PM) level benefits producing complicated systems
- What form should systems engineering look like in a complex organization such as a PEO?

Complexity – effects on systems

- Systems become open
- Systems behaviors aren’t reducible to the sum of their parts
- Systems parts interact nonlinearly
- More difficult to completely comprehend systems
- Is a fundamental reason for failure in large scale engineering projects[3]

Complex Systems

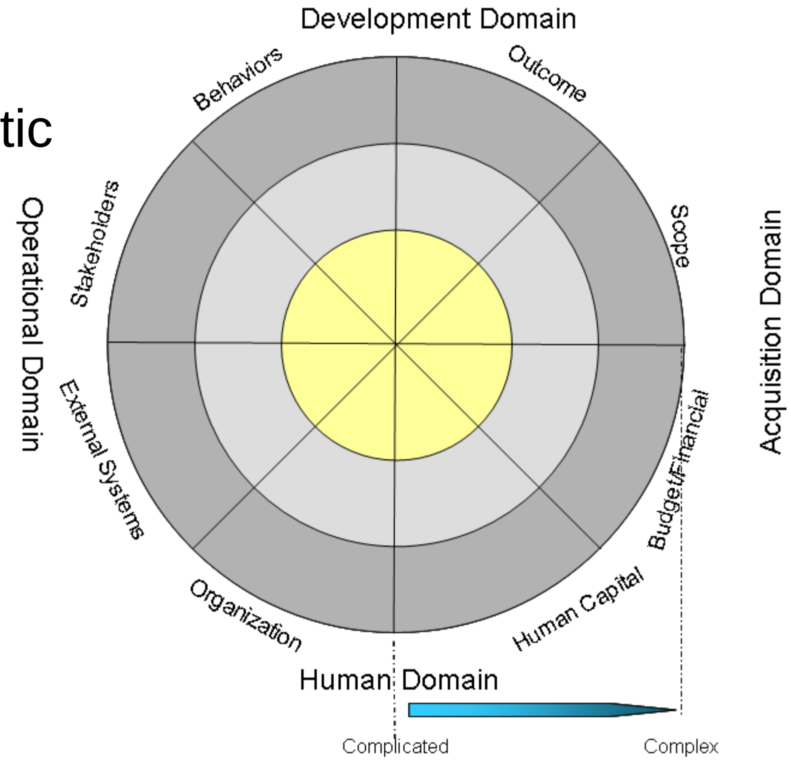
- Focus is on the overall coherence of the whole complex system – without direct, immediate attention to the details while typical engineering tends to focus on the functional description
- Emphasis is on how decisions are made and not what those decision should be
  - The order and complexity of the solution rather than a pre-specified solution
  - What parts of the whole solution should addressed
- Relationship and interaction of the population associated with the complex system development is key

Complex Systems (cont)

- Development characteristics- Shapes the environment and not the actual development
  - Variety of autonomous agents. Ability to add and remove agents without halting the system
  - Enable autonomous agents interaction
  - Resources flow throughout the development without any prescribed means, based on cooperation and competition
- Operational characteristics
  - Because complex systems evolve – direct interaction is needed between development and operational
  - Only non complex systems can be treated in a way of isolating development from operation
- Enterprise is a complex system

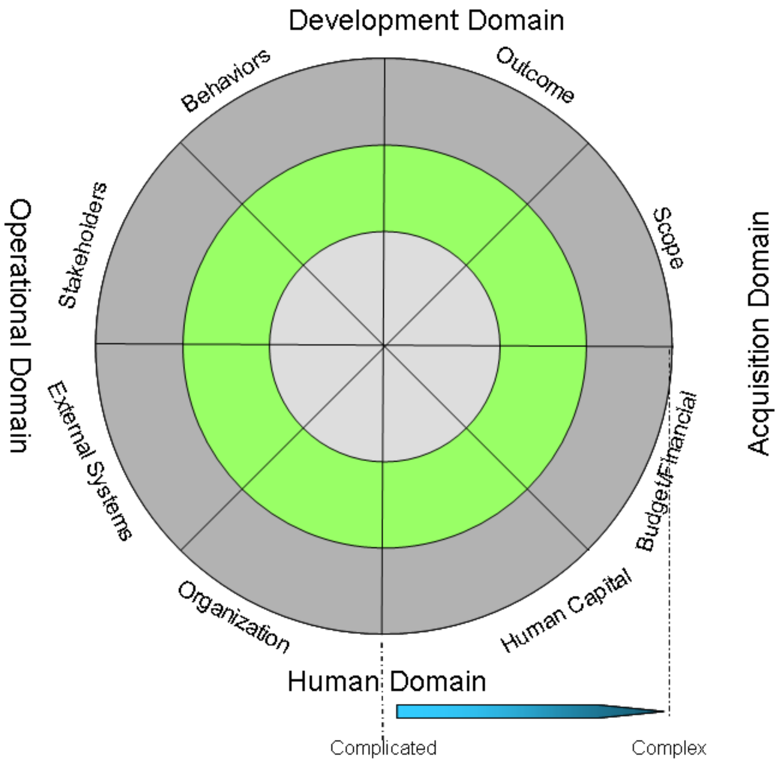
Systems Engineering

- Development Domain
  - Behaviors- definable
  - Outcome/Reward – predictable/static
- Acquisition Domain
  - Scope – linear/closed boundary
  - Budget/Financial –systems owned
- Human Domain
  - Human Capital - skills are understood (classical)
  - Organization-defined & structured
- Operational Domain
  - External Systems- single interface
  - Stakeholders- single user class



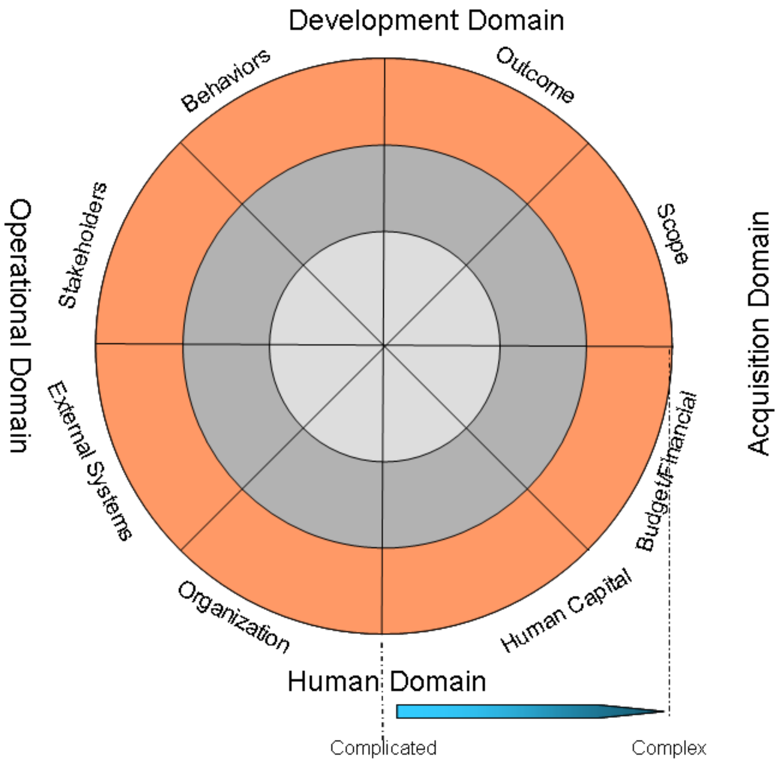
System of Systems Engineering

- Development Domain
  - Behaviors- identifiable
  - Outcome/Reward – predictable/dynamic
- Acquisition Domain
  - Scope – linear/complicated boundaries
  - Budget/Financial – systems shared
- Human Domain
  - Human Capital - skills are diverse
  - Organization- complicated & relational
- Operational Domain
  - External Systems- multiply systems – similar interfaces
  - Stakeholders- similar users



Enterprise Systems Engineering (ESE)

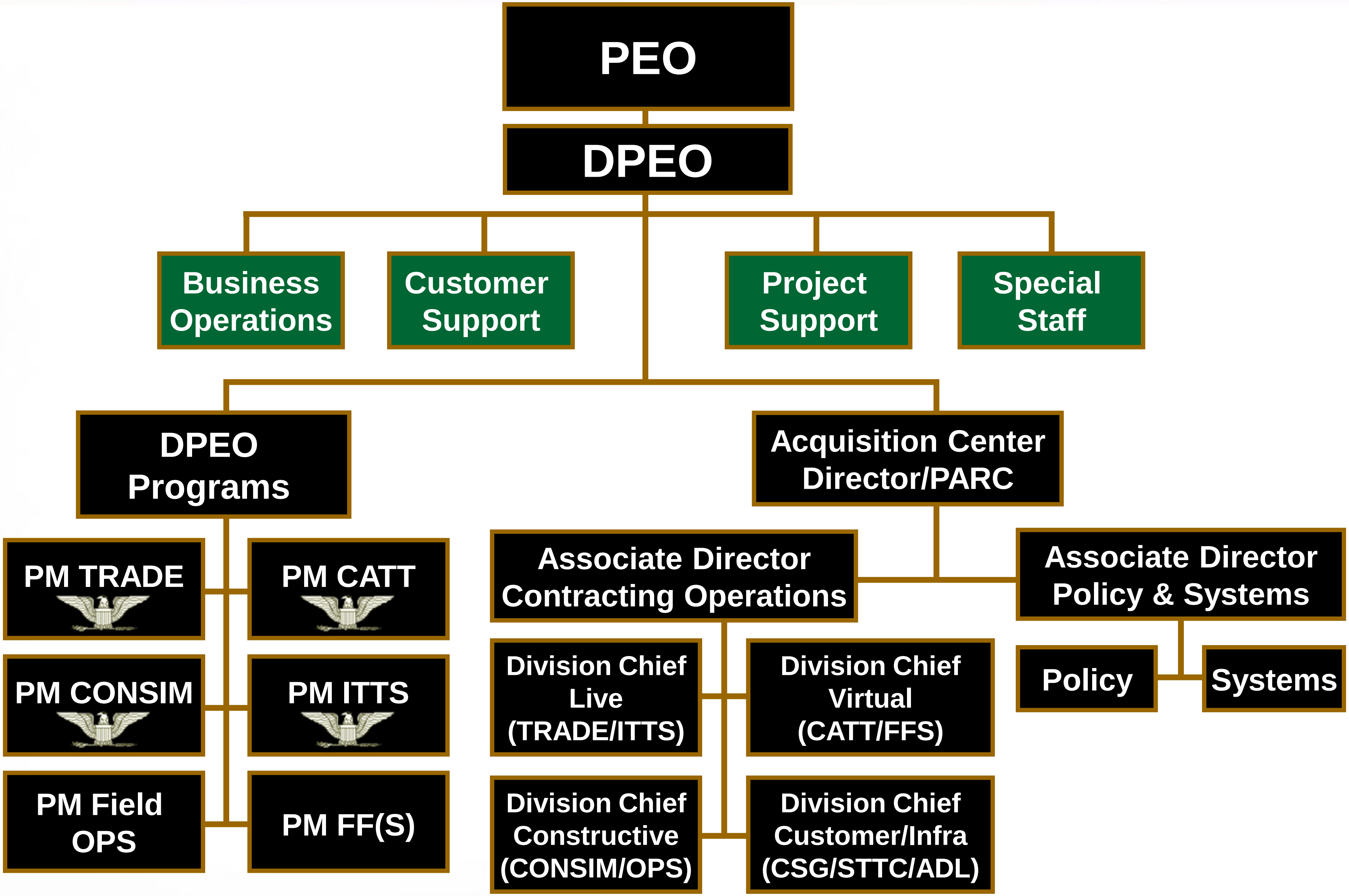
- Development Domain
  - Behaviors- self organizing/open
  - Outcome – adaptable/flexible
- Acquisition Domain
  - Scope –nonlinear/open boundary
  - Budget/Financial – systems advocacy
- Human Domain
  - Human Capital - skills are diverse
  - Organization- distributed & cooperative
- Operational Domain
  - External Systems- multiple systems – multiple interfaces
  - Stakeholders- multiple users



Systems Engineering in Complex Organization – Use Case Example

- Program Executive Office – Simulation, Training, and Instrumentation (PEO STRI)
  - Complex Organization
  - Complex Systems and System of Systems
- Conceptual application of "enterprise-level" Systems Engineering best practices to support the PEO's SoS problem space of integrating the Live Virtual Constructive (LVC) domains.
  - Utilized SE technical management processes such as technical planning, requirements management and interface management

PEO STRI Organization



PEO

DPEO

Business Operations

Customer Support

Project Support

Special Staff

DPEO Programs

- PM TRADE
- PM CATT
- PM CONSIM
- PM ITTS
- PM Field OPS
- PM FF(S)

Acquisition Center Director/PARC

Associate Director Contracting Operations

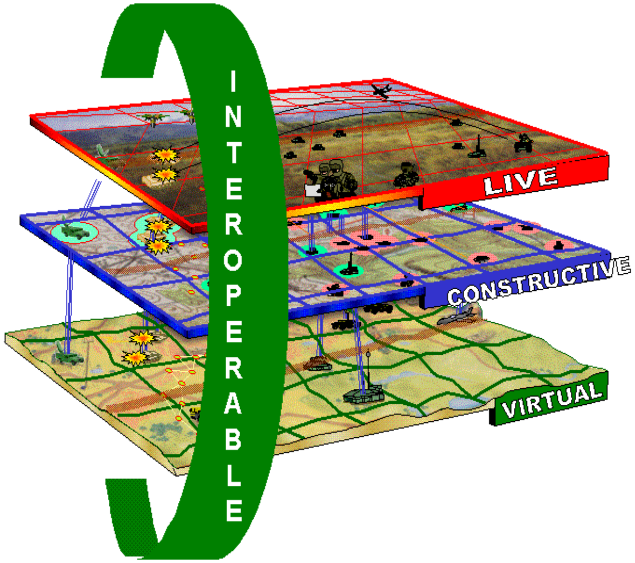
- Division Chief Live (TRADE/ITTS)
- Division Chief Virtual (CATT/FFS)
- Division Chief Constructive (CONSIM/OPS)
- Division Chief Customer/Infra (CSG/STTC/ADL)

Associate Director Policy & Systems

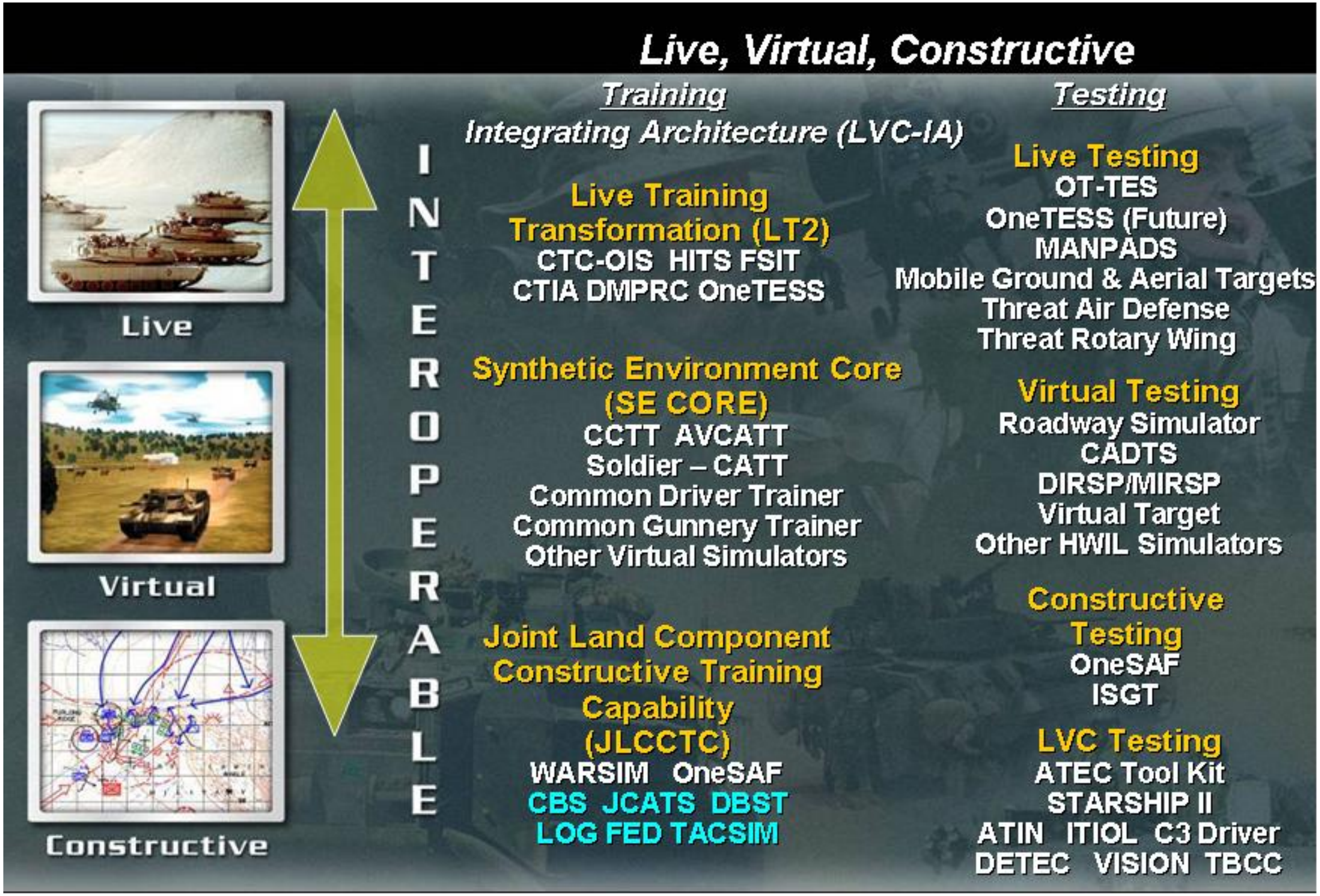
- Policy
- Systems

PEO STRI Mission-Complexity Space

- Provide a modular, agile, simulation, training, testing, and instrumentation environment to enable Warfighter success for any threat
- We must capitalize on the Army's investment through integration and interoperability (I2)
- Achieved through leveraging and reuse of capabilities across the PEO's Enterprise (i.e.: Standards, Common Products, etc.)
- Provide effective and efficient lifecycle managements of simulations solutions to support the Warfighter



A Complex System – LVC Interoperability



Live, Virtual, Constructive

Live

Virtual

Constructive

INTEROPERABLE

Training

Integrating Architecture (LVC-IA)

Live Training Transformation (LT2)
CTC-OIS HITS FSIT
CTIA DMPRC OneTESS

Synthetic Environment Core (SE CORE)
CCTT AVCATT
Soldier – CATT
Common Driver Trainer
Common Gunnery Trainer
Other Virtual Simulators

Joint Land Component Constructive Training Capability (JLCCTC)
WARSIM OneSAF
CBS JCATS DBST
LOG FED TACSIM

Testing

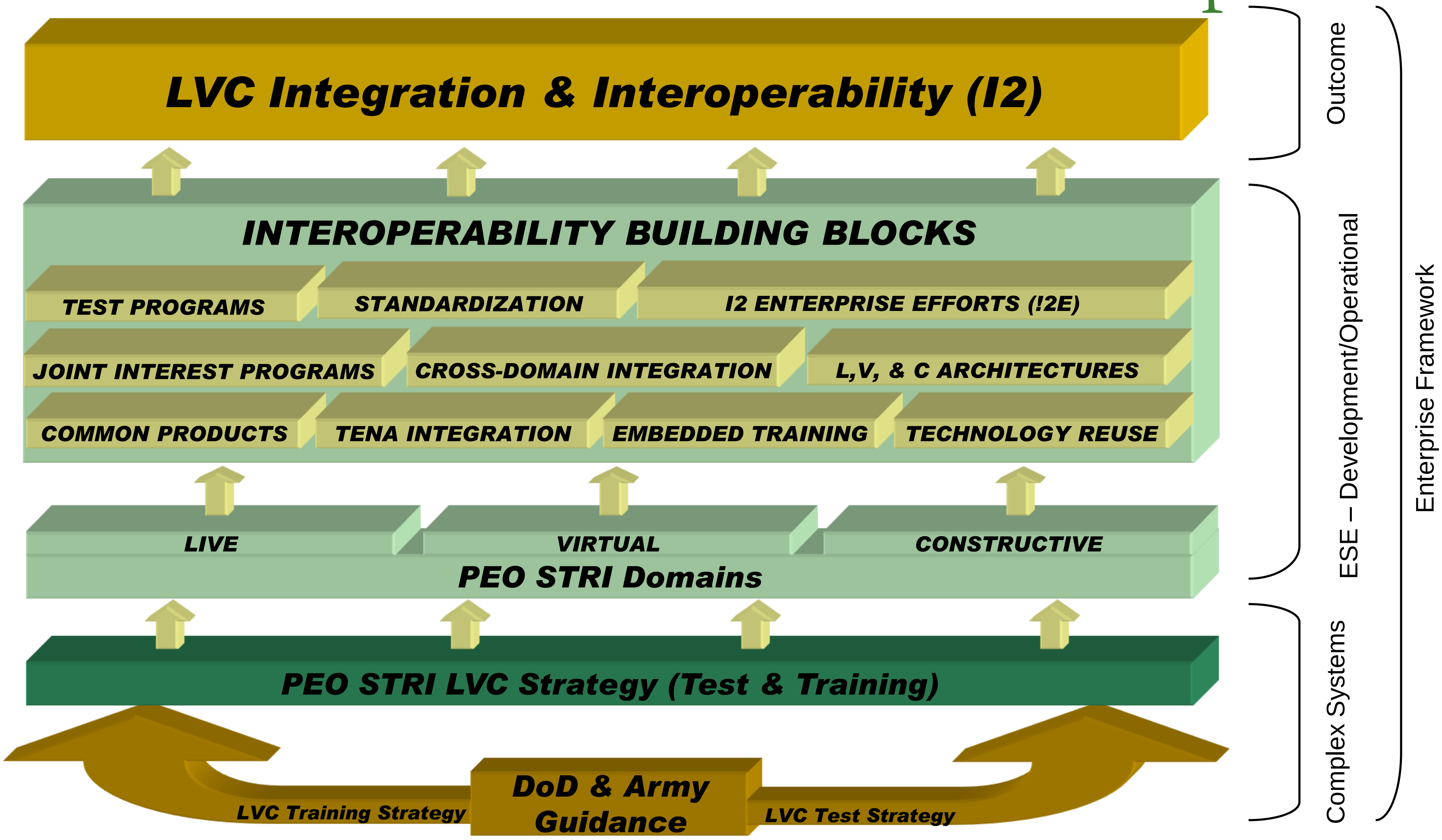
Live Testing
OT-TES
OneTESS (Future)
MANPADS
Mobile Ground & Aerial Targets
Threat Air Defense
Threat Rotary Wing

Virtual Testing
Roadway Simulator
CADTS
DIRSP/MIRSP
Virtual Target
Other HWIL Simulators

Constructive Testing
OneSAF
ISGT

LVC Testing
ATEC Tool Kit
STARSHIP II
ATIN ITIOL C3 Driver
DETEC VISION TBCC

LVC I2 – ESE Framework Example



Applying ESE – Developmental Environment

- Single most basic activity underpinning engineering enterprise systems
- Create environment of continuous innovation to address complexity
- PEO STRI established a group called the Integration/Interoperability Advisory Board (I2AB) to provide governance to technical and PM processes
  - I2AB provided the forum for team organization and open communications across the PEO domains
  - Comprised of technical and programmatic leaders from each of the L/V/C domains
- I2AB creates coherence
  - Requirements Management
  - Interface Management

I2 Advisory Board (I2AB) Characteristics

- **Responsible to provide management oversight, direction, and guidance of I2 mission.**
- **Comprised of both PEO technical and program senior leadership and reports to the PEO Board of Directors (BOD).**
- **Provides technical and program recommendations to the DPEO/ BOD to facilitate I2 across the PEOs program portfolio.**
- **Manage the PEO portfolio Dependency Matrix.**
- **Establishes I2 standards, guidelines, and processes for use and compliance in coordination with PMs.**
- **Defines I2 policies for PEO implementation.**
- **Educates community on I2.**

Requirements Management

- I2AB understood basic complexity principal to cope with SoS complexities requires increased flexibility
- SoSE requires adaptation to changing requirements
- Utilize DODAF to develop “enterprise” architecture artifacts to support interoperability and information exchange requirements for LVC
  - Methods and information
  - Functions, processes, activities, data elements
  - Standards

Interface Management

- I2AB understood the importance of "standards-compliance" as an asset to support interoperability
- I2AB developed and enforced the use of the PEO's Common Standards, Products, Architectures and Repository (CSPAR)
- Initiated the Live, Virtual, Constructive Integration Cell (LVCIC) effort to begin integration of key systems/interfaces for the LVC Integrated Training Environment (ITE).

ESE LVC Outcome Challenges

- Data Model Strategy that supports efficient LVC Training and Testing – modeling across systems
  - Fair fight
- Consensus on what is "good enough" – defining the "right" MOE/TPMs that apply to the SoS
  - Use LVC Interoperability Model as "measuring stick"
  - Ensure fidelity and density of data and signals meets needs of both test and training communities
  - Address security of data issues across all communities
- Defining clear LVC use cases
- Resources that specifically address LVC requirements
- Common Test / Training Solutions
- Scalability of LVC products – Different requirements for each domain

Summary

- Complexity – Impact on Systems
  - ❑ Complex organization are complex systems
  - ❑ Complex System are open
  - ❑ Complexity makes it more difficult to completely comprehend a system
- Why Enterprise Systems Engineering?
  - ❑ Complex systems don’t decompose well and tend to be nonlinear
  - ❑ Complex systems behaviors are not predictable
  - ❑ Therefore, classical systems engineering approaches need modification
- Keystone concepts to ESE approach
  - ❑ Configure for the context and local interaction and not detailed design
  - ❑ Incorporate processes to handle unforeseen changes in behavior
  - ❑ Include multiple methods for achieving the same end
- Potential Benefits to PEOs
  - ❑ Complex systems that are flexible and adaptable
  - ❑ Ability to evolve systems through introduction of new technology with out disrupting the systems
  - ❑ Ultimately, reduces risks caused by unanticipated effects that lead to failures of systems

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