New Perceptions in Coping with System of Systems (SoS)

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New Perceptions in Coping with SoS

- SoS Definitions
- OSoS Characterizations, Parameters and Types
- Rationale for Defense Industry Entry in OSoS Development
- OSoSE Versus Systems Engineering
- OSoSE Recommendations
- OSoS Management Highlights
How to Define SoS?


- For example: one fighter aircraft incorporates many systems, but SoS refers to entire squadron!

- To be clear, I propose the term Operational SoS (OSoS)
Operational SoS Definition

Ensemble of platforms, armaments, equipment, C4I, personnel, training and maintenance facilities.

These synergistically work together to achieve set of tasks within a defined mission, according to operational methodologies driven by combat doctrine.
OSoS Example

FCS (Future Combat System)

- OSoS includes
  - Platforms
  - Weapons
  - C^4I2SR
  - Doctrine
  - Training facilities
  - Fighting Units
  - Soldiers
  - Maintenance
  - ILS (Integrated Logistic Support)
FCS OSoS - Concept of Operations

CONUS Higher HQs
En Route Planning
Rehearsal

Joint & Coalition Assets

National ISR

Satellite Communications

Joint ISR

Objective
Operational &
Tactical Forces

NLOS Command

FCS Battle Brigade
C2 Subsystem

Coalition Forces

Dismounted
Combat Team A

Combat Team B

UAV

Legend: Interfaces
- Intra-FCS
- Interoperable

NGO
OSoS Characterizations

- Trained personnel are integral part of OSoS
- OSoS building blocks can be distributed at remote locations and interconnected by communication networks
- C^4I systems are critical “glue” for combining separate systems into OSoS
- Coordinated operation of all OSoS building blocks is key factor in effective and efficient mission accomplishment
- OSoS concept, architecture and capabilities are being consolidated in parallel with evolutionary development of its operational methodology
OSoS Types

- Dedicated vs Virtual OSoS
- Preplanned vs gradually-developed OSoS
Rationale for Defense Industry Entry into OSoS Development

- Defense market customers new attitude is to deal with OSoS - defining requirements, evaluating and ordering OSoS - and not separate systems.

- Many advantages for main contractor:
  - Increasing reputation as leading defense industry
  - Enabling direct interaction with customers including End Users
  - Improving opportunity to incorporate own advanced technologies
  - Improving own capabilities when coping with OSoS Systems Engineering (OSoSE)
OSoSE vs Systems Engineering

- Starting OSoS Program
- Requirements consolidation and management
- Functional Analysis
- Interfaces definition
- Modeling and Simulation
- Defining and executing V&V
- Evolutionary behavior of OSoS
- Architectural analysis of OSoS
- Deep involvement of interested parties
**OSoSE vs Systems Engineering**

- **Starting OSoS Program**
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**Very long processes together with interested parties and customers to refine concept**

**Early consolidation of Strategic Partners**

**Considerations of using state-of-the-art or just Foreseen Technologies**

**Starting interim developments to reduce risks and/or to verify new concept (usually the proven concepts become constraint in the full scale program)**
OSoSE vs Systems Engineering

Starting OSoS Program
- Requirements consolidation and management

Very high level of complexity in consolidating requirements for new OSoS:
- many customers with different interests,
- evolutionary nature of development, and
- necessity for interoperability

Requirements develop and are updated during entire OSoS life cycle

Connectivity and interfaces with neighboring OSoS under development

Advanced software tool is needed to handle the huge requirements scope (the original + derived ones) and their complex linkages
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Processes, tasks and scenarios in OSoS are complex, involving many components.
These create interactive constraints and mutual effects.
Conclusion: Methodical Functional Analysis is critical for architectural consolidation of OSoS.
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**Systems Engineering**
defines mechanical, electrical, computational - connectivity and MMI interfaces

**OSoS** provides upper layer of different types of scenarios and tasks:
Physical: different configurations and Logical: different tasks

Result: Different interface requirements for various applications
OSoSE vs Systems Engineering

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Not possible to produce complete model of OSoS to simulate all its functionality as:
- Infinite cases of possible events and scenarios included
- Very difficult to simulate human behavior
These situations require:
- Using many models to cover all hierarchy levels
- Simulating tasks management with Humans-in-the-Loop
- Developing special simulation concepts and tools to cope with OSoS

Example: GES4
OSoSE vs Systems Engineering

- Complex V&V procedures: analysis, simulations, integrations and tests
- Verification of the design in stages, combined with risk analysis and plans

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- Interfaces verification at all levels, scenarios and tasks
- OSoS validation in series of high-level preplanned test scenarios
OSoSE vs Systems Engineering

- **OSoS Life Cycle Concept**: taking into account existing systems, future development and stages in life cycle and life time
- **Adaptive development**: considering unexpected changes in directions as result of operational lessons learned by early fielded models
- **Development environments**: as teams, subcontractors, knowledge, experts, tools – are changing!
- Evolutionary behavior of OSoS
- Architectural Analysis of OSoS
- Deep involvement of interested parties
OSoSE vs Systems Engineering

Definition: Model description (physical, functional, operational, software etc) at OSoS upper level in its relevant environment, considering its evolutionary and open system natures.

Architectural Analysis of OSoS require very high level of professionalism in following issues:
- Methodology
- Tools
- Training
- Experts

Evolutionary behavior of OSoS

Architectural Analysis of OSoS

Deep involvement of interested parties
OSoSE vs Systems Engineering

- Range of interested parties usually with contradictory interests! - including main contractor and subcontractors, customers taking part in development and end users

- OSoS military aspects require close involvement of customer as early as possible with professional teams who can make difficult decisions!

- Close cooperation with customer and mutual obligations are essential for successful building of OSoS!

- Deep involvement of interested parties
OSoSE Recommendations

- Methodology
  - New special upper level of Systems Engineering Process **to be defined** (V model recommended)

- Interoperability and MOSA (Modular Open System Approach) in OSoS **to be adopted**

- Professionalism of OSoS Architecture and function of Chief Architect (compared to Chief Systems Engineer) **to be cultivated**
OSoSE Recommendations

- **Organization**
  - Chief Architect, responsible for all aspects of OSoS Engineering, directly subordinate to Program Manager/Management
  - Working with Integrated SE Team (ISET)
Integrated SE Team for OSoS (ISET)

- OSoS Architect
- Integrations, Simulations & Test Team
- Requirements Team
- Functional Analysis Team
- Concurrent Engineering Team
- OSoS Architecture Team
- Joint Customer Team

Systems:
- System A
- System B
- System C
- System D
- System E
- System F
- System G
OSoSE Recommendations

- **Tools**
  - Central database
  - Creating and preserving logical connections with full traceability
  - On-line coordination between all development bodies
  - Automatic documents production
  - Fast transformation from UC analysis to working software implementation
  - Massive supportability

Examples: Core, Requisite Pro, Clear Case, Rhapsody, Doors
OSoSE Recommendations

- Critical technology disciplines and infrastructure required for OSoSE
  - Information (collecting, processing, distribution)
  - Intelligence (collecting, decoding, data fusion, processing, distribution)
  - Sensing (electro-optical, acoustics, RF,...)
  - C⁴I²SR
  - Interdisciplinary and multidisciplinary know-how such as:
    - Image processing with navigation
    - Communication with missile guidance, control and navigation
    - Intelligence with signal processing, pattern recognition;
    - and more...
OSoS Managements Highlights

- Coping with OSoS provides main contractor with many advantages and benefits - and it’s worth it!

- Spiral development of OSoS ensures use of most updated technologies and capabilities available while dealing with enemy emergent threats, in process that allows step-by-step fielding
OSoS Management Highlights

- Recommended to manage OSoS architecture and systems engineering processes through Chief Architect and Integrated SE Team

- Use specific gates and checklists as necessary management tool in building OSoS

- Common methodologies, tools and Infrastructure for all parties and bodies involved in development of OSoS is key to success!
OSoS (Operational SoS) is proposed as a common term to which Defense industry can refer.

New level of complexity - not just “more” regular Systems Engineering – it requires development of new concepts, approach and methodologies.

It’s a challenge!

It’s worth it!
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Thanks for listening!

Questions?

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Speaker background:

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**Ph.D.** in Aeronautics & Astronautics, 1985, Stanford University, California, USA. (Thesis: “Composite Barriers and Corner Conditions in Differential Games”)

Rafael – Armament Development Authority Ltd., Israel:
Since 1969: group leader, systems engineer, chief engineer, manager of Antitank missile directorate, VP for R&D, VP Chief Systems Engineer, Corporate Chief Scientist


**Prize:** Israel National Defense Prize (1984)
C4I2SR

- Command Control, Communication, Computers
- Intelligence, Information
- Surveillance
- Reconnaissance