System of Systems

Technology Readiness Assessment

WindyJoy Majumdar

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 2007		**00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
System of Systems Technology Readiness Assessment	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Single Integrated Air Picture Joint Program Ofc,1851 S Bell St,Arlington,VA,22202**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002182. Presented at the AFRL Technology Maturity Conference held in Virginia Beach, VA on 11-13 September 2007.

14. ABSTRACT

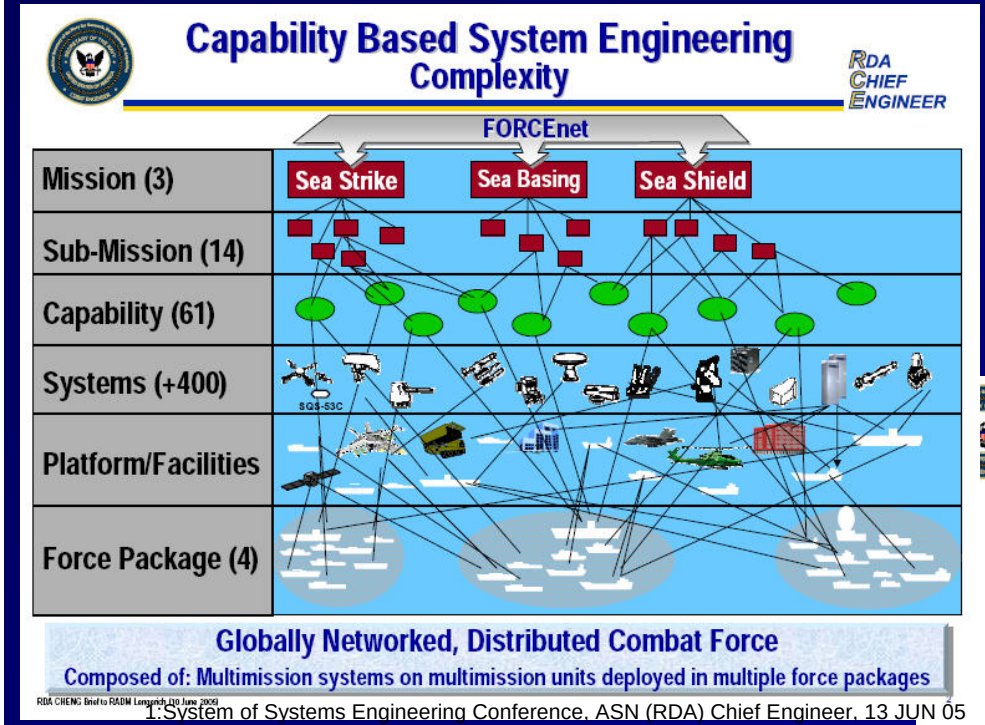
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**29**	

Agenda

- Net-Centric Challenges
- SoS Technology Readiness Assessments (TRA)
- SoS TRA Checklist
- SoS TRA Acquisition Challenges
- SoS TRA example
- SoS Way Ahead

Net-centric Challenges

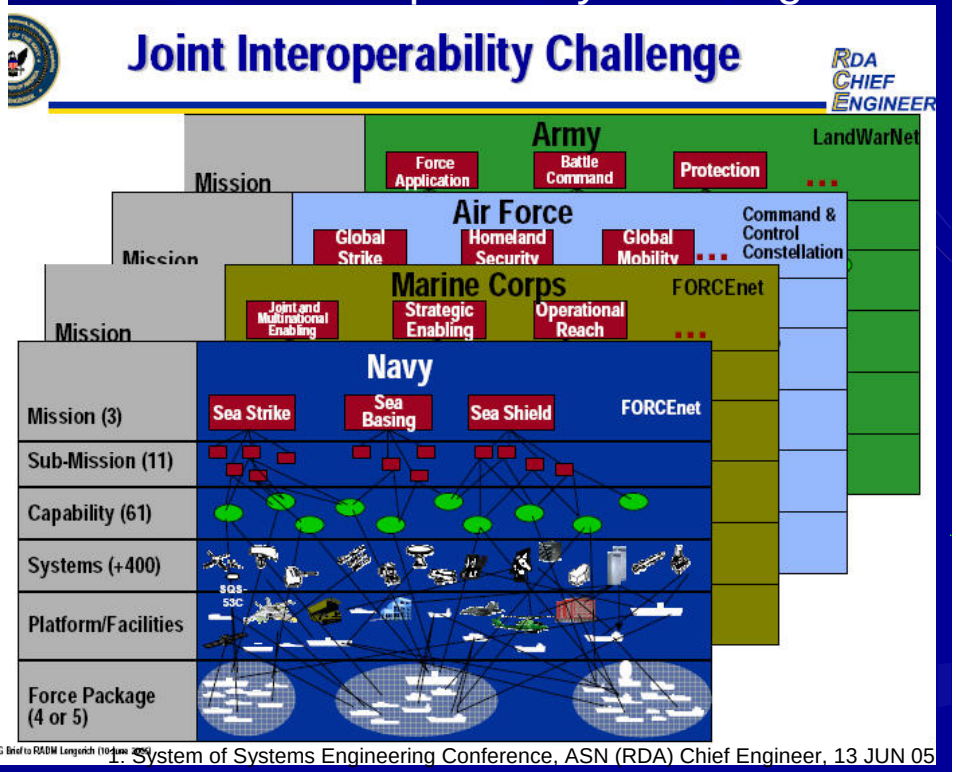


1.System of Systems Engineering Conference, ASN (RDA) Chief Engineer, 13 JUN 05

Service Interoperability Challenge

Interoperable Service and Joint Systems

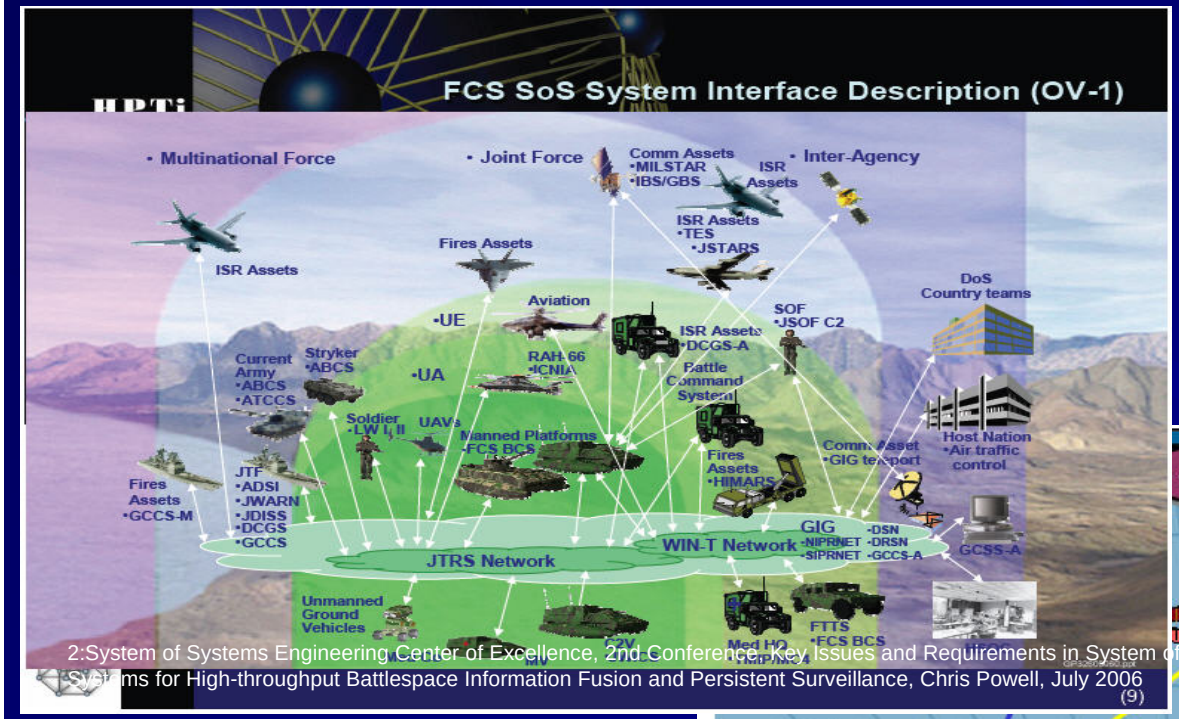
Joint Interoperability Challenge



1. System of Systems Engineering Conference, ASN (RDA) Chief Engineer, 13 JUN 05

Legacy, New and Mixed Systems

FoS and SoS Currently in Development



2:System of Systems Engineering Center of Excellence, 2nd Conference, Key Issues and Requirements in System of Systems for High-throughput Battlespace Information Fusion and Persistent Surveillance, Chris Powell, July 2006

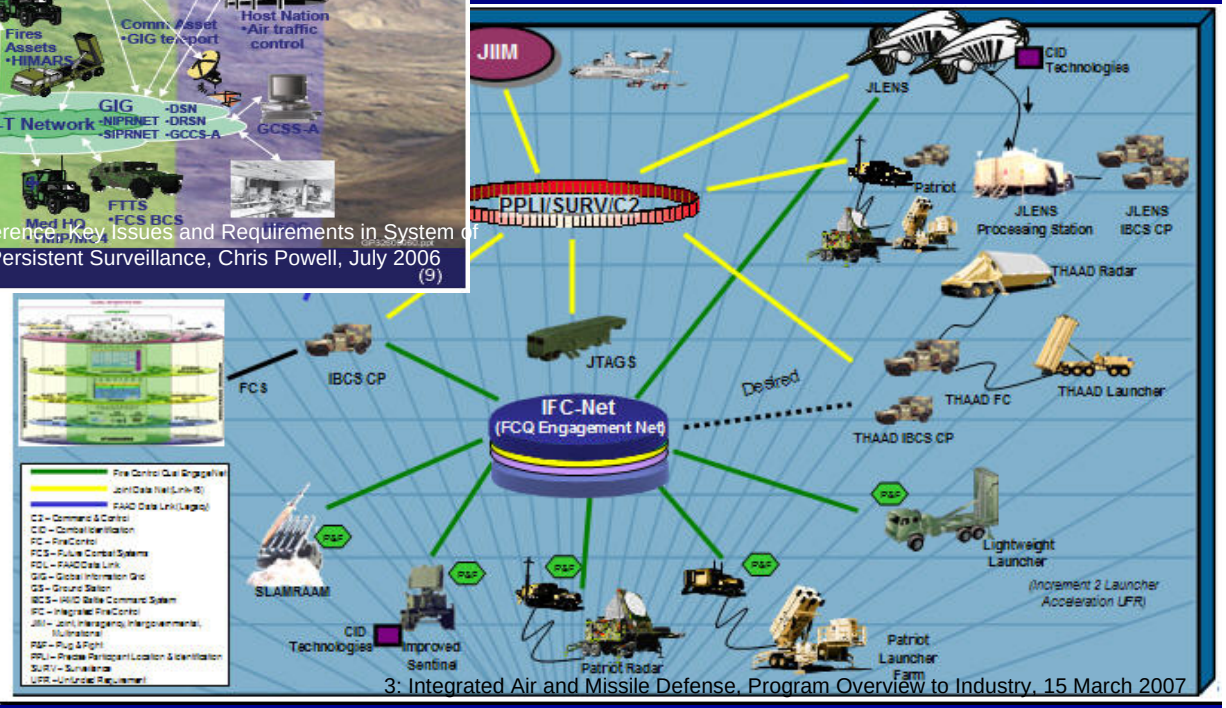
(9)

Army's Future Combat System

FoS achieved via SoS common operating environment

SoS achieved via common modules

Army's Integrated Air and Missile Defense SoS



3: Integrated Air and Missile Defense, Program Overview to Industry, 15 March 2007

Types of Systems

System

… **components** that are connected to provide a given capability…loss of any part of the system (without redundancy) will result in a failure of the system.

- **KPPs met by one system during independent operations**
- **TRL 6 – system**

Family of Systems (FoS)

…A **set of systems** that provide similar capabilities through different approaches to achieve similar or complementary effects… does not create capability beyond the additive sum of the individual capabilities of its member systems

- **KPPs met by individual systems in context an cooperative operations**
- **TRL 6 – system**

System of Systems (SoS)

… **interdependent systems** that are connected to provide a given capability…loss of any part of the system will significantly degrade the performance or capabilities of the whole (without redundancy).

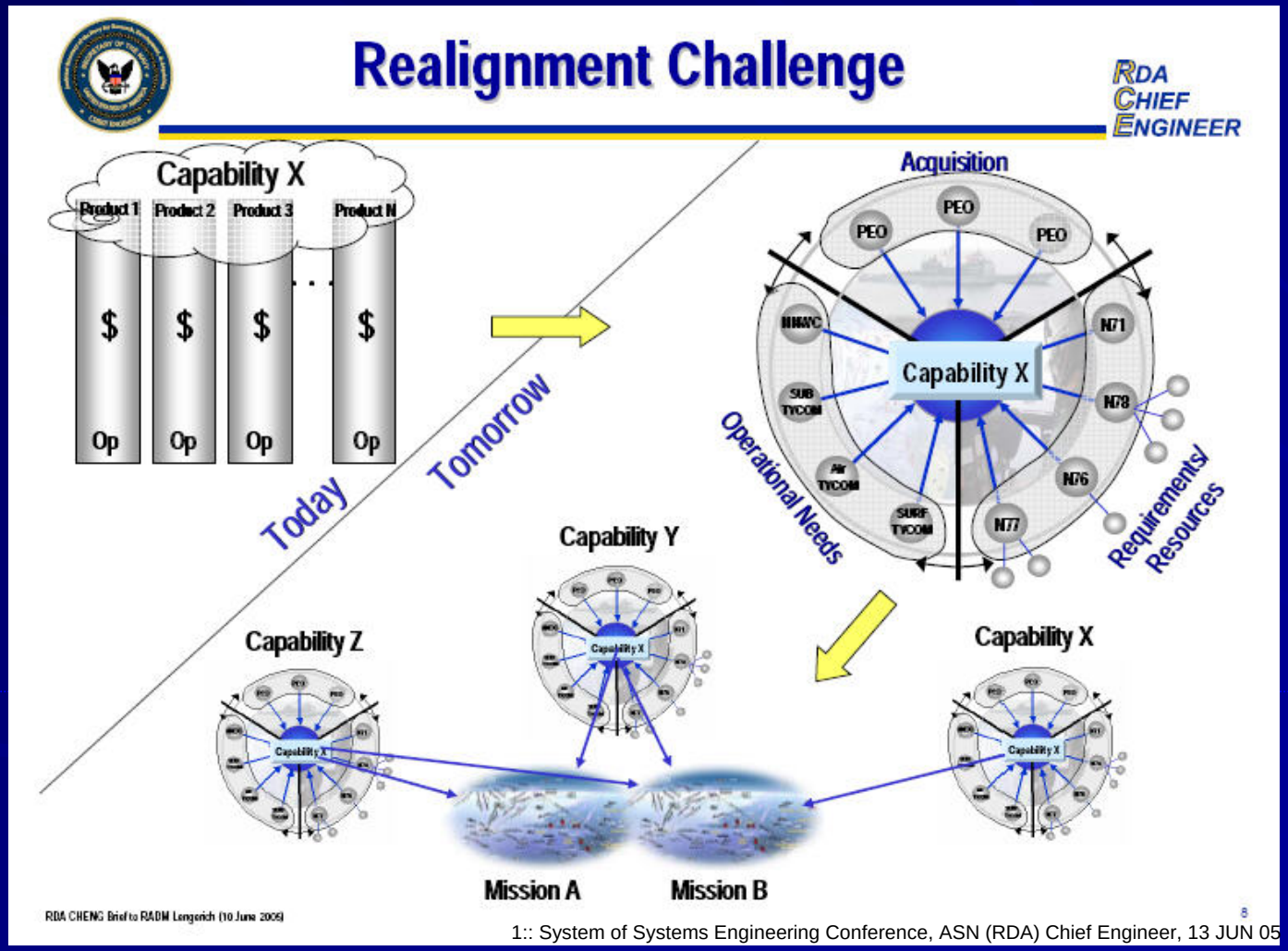
- **KPPs met with multiple systems in collaborative operations**
- **TRL 6 – system and SoS**

SoS Technology Readiness Assessments

SoS and System TRAs – any difference?

- Operational relevant environment
- Critical technology elements (CTEs)
- Acquisition milestones

Operational Relevant Environment



1:: System of Systems Engineering Conference, ASN (RDA) Chief Engineer, 13 JUN 05

Moving From System-centric to Net-centric

Interoperability

- The forces, units, and systems of all Services must operate together effectively

  … interoperability should be achieved primarily by a commonality of equipment, software, and systems both horizontally and vertically

- The ability to operate in synergy in the execution of assigned tasks.

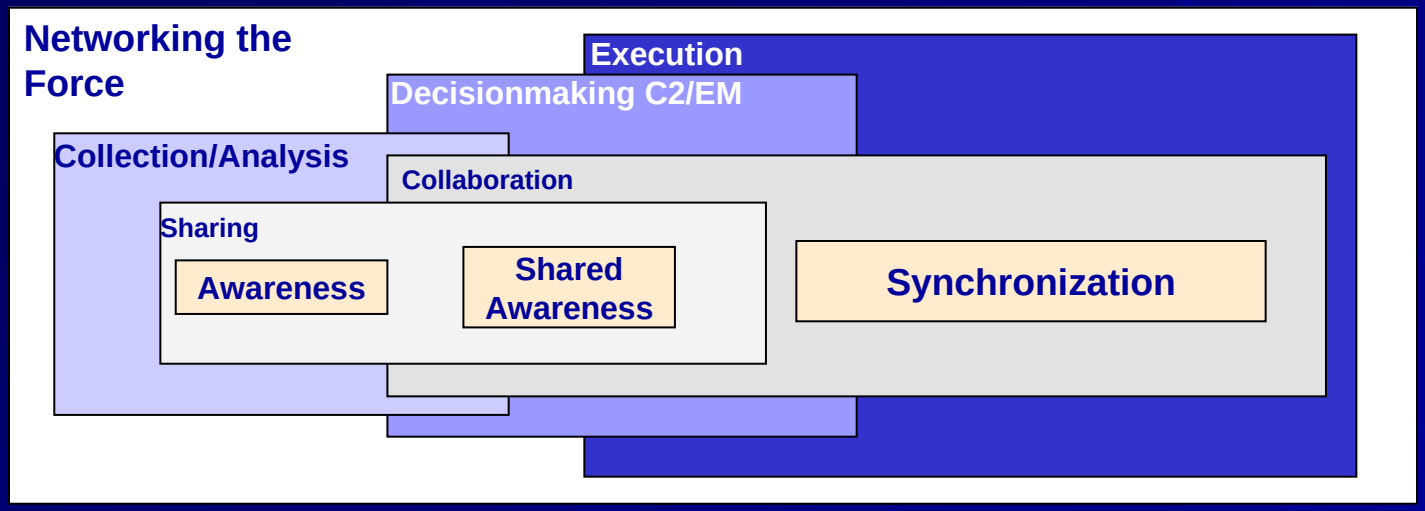
- The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.

"The degree of interoperability should be defined when referring to specific cases."

4. Joint Chiefs of Staff Joint Pub 1-02,12 April 2001 as amended through 13 June 2007

Degrees of Interoperability

Operational Environment



Networking the Force Mental Model { 5.Alberts, David S. 2001}

Interoperability

- Awareness/Collection thru **coordinated** operations
- Shared Awareness/Decision Making thru **cooperative** operations
- Synchronization to enable **collaborative** execution of operations

Degree of Interoperability (con't)

- Awareness/Collection thru **coordinated** operations
  - **Systems** provide data/information primarily via voice and standard data link messages
  - Coordinated operations by rules, not specifically coupled
- Shared Awareness/Decision Making thru **cooperative** operations
  - **Family of Systems** provide data/information via standard data links and possible use of uniquely specified messages
  - Cooperative operations loosely coupled via common applications
- Synchronization to enable **collaborative** execution of operations
  - **System of Systems** provides data/information via standard data links and use of uniquely specified application and service messages
  - Collaborative operations tightly coupled through common distributed processing of data/information and real-time communications

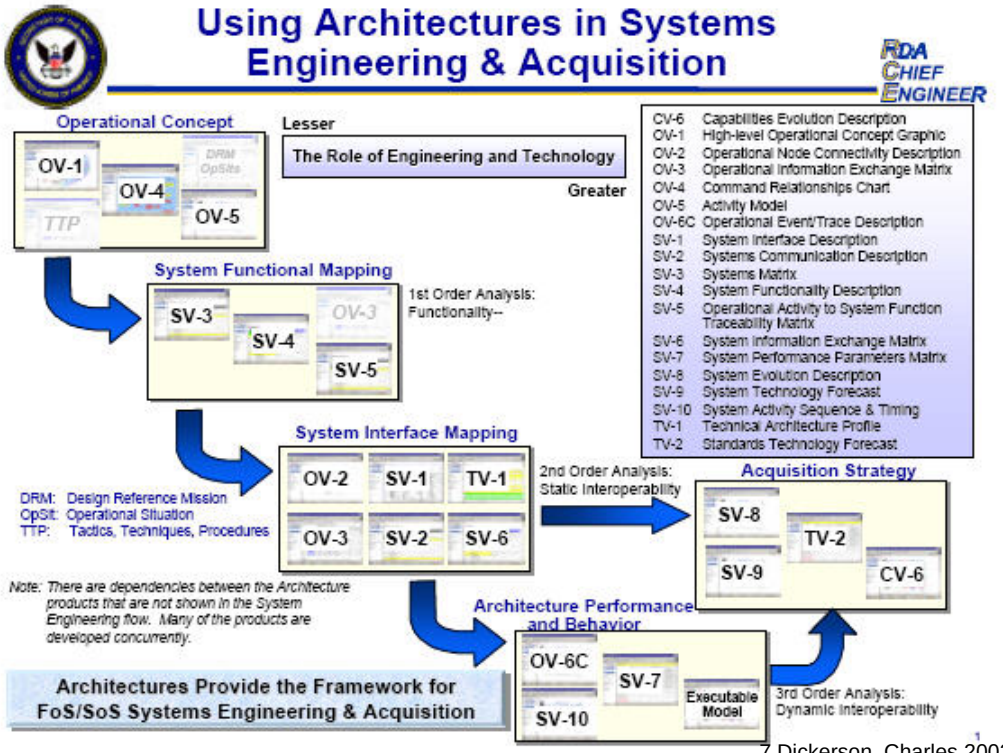
Interoperability Attributes

CTEs enable functionality, behavior and performance:

- Completeness - all relevant items available, including entities, their attributes, and relationships between them
- Correctness - all items in the system faithful representations of the realities they describe)
- Currency – latency of the items of information is minimized
- Accuracy or Level of Precision (which is conditional on the purpose the user has in mind)
- Consistency - across different systems, application dependencies, functional interdependencies, application and data interrelationships
- Connectivity – specified integration of nodes, type of connections, syntactic compatibility, quality of service and bandwidth/data rate requirements
- Capacity – databases, scalability, number and type of applications

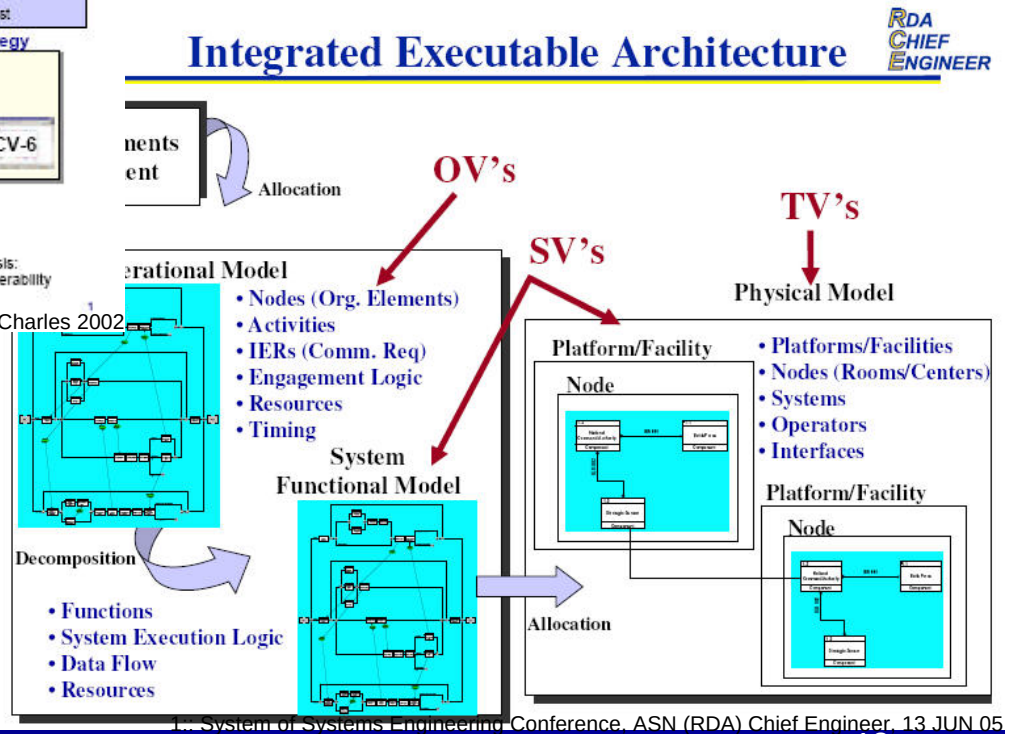
[After 5 Alberts, David S. 2001]

TRA CTE Identification



7 Dickerson, Charles 2002

Architecture and Engineering Artifacts key to identifying interoperability CTEs



1st System of Systems Engineering Conference, ASN (RDA) Chief Engineer, 13 JUN 05

SoS TRA Checklist

- Operational
  - Key Performance Parameters (KPPs) and CONOPs
- System Architecture
  - Boundary(ies) to measure KPPs
- Functional Architecture
  - Degree of integration
- Technical Architecture
  - Standards, protocols

- Completeness
- Correctness
- Currency
- Accuracy or Level of Precision
- Consistency
- Connectivity
- Capacity

SoS Technical Challenges

- SoS Architecture and Capability Engineering prior to system engineering and technology development

  ... many SoS are assembled from legacy systems and net-centric functionality may be constrained

- Key Performance Parameters (KPPs) allocation to individual systems

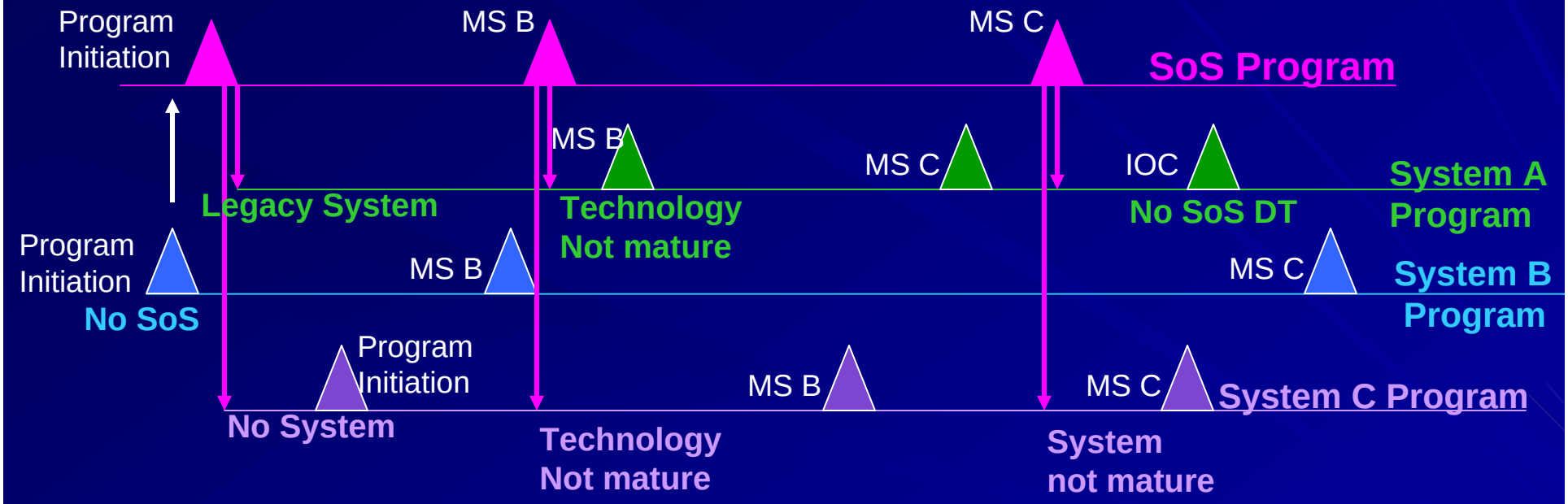
- SoS relevant environment modeling and simulation and test and evaluation environments built post system design and development

- Critical (interoperability) technology elements identification may not be obvious within a (re)composable context or environment

- Typically enabled with software which is easily changed incrementally over time with new technologies and in response to different requirements

SoS Synchronization Challenges

SoS Program Unsynchronized:

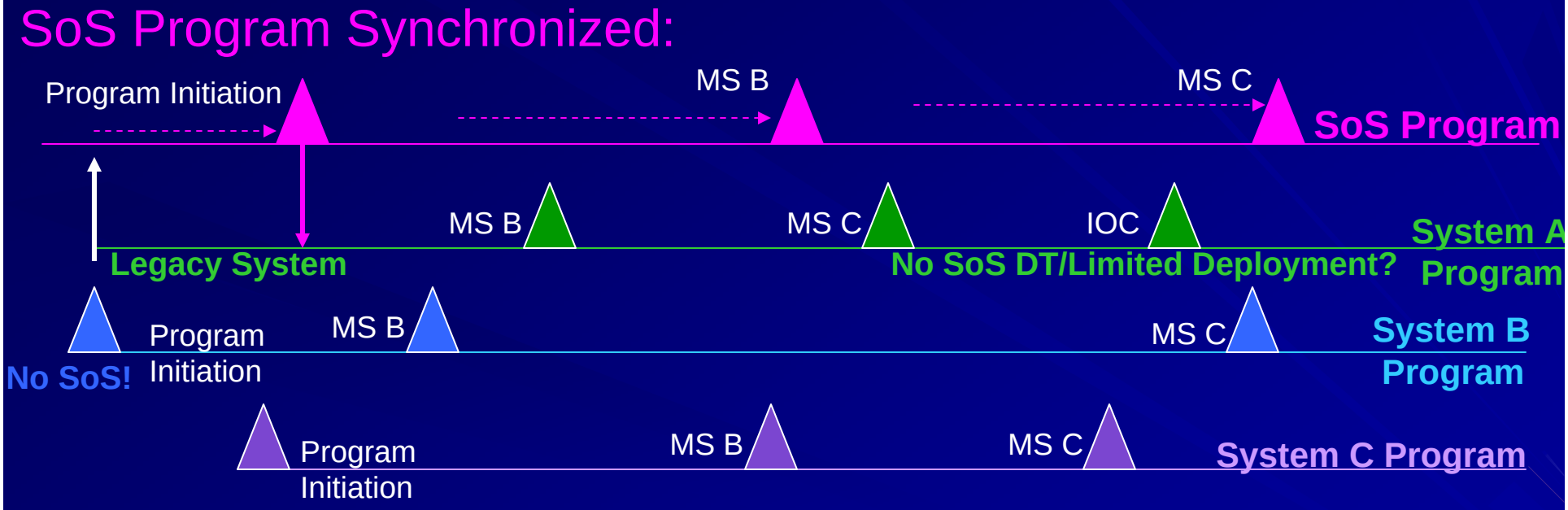


- System B program initiation prior to SoS program initiation
- SoS program initiation – System A and C not yet participating in SoS
- SoS MS B – Only System B has mature technologies, System A - legacy technologies
- SoS MS C – No SoS testing for TRL 7 possible

SoS Engineering through System Functional Review prior to a MS B least risk

Milestone (MS)

SoS Synchronization Challenges (2)



- System B program initiation prior to SoS MS A – SoS Engineering delayed
- SoS program initiation – Start SoS Engineering Activities and fund systems to participate
- SoS MS B – Hold after systems have SoS mature technologies
- SoS MS C – Hold after SoS testing possible; System A - limited SoS deployment

SoS Engineering through System Functional Review prior to a MS B least risk

Milestone (MS)

SoS Acquisition Challenges

- Multiple Systems acquired asynchronously
  - Technology developments not in alignment with SoS acquisition milestones
  - SoS Engineering activities not complete given not all systems funded or developed simultaneously
  - SoS milestone alignment with mix of new and legacy systems milestones
- Blocks/Spirals developed over several years
  - Technologies change over time or may not be available to all systems
  - SoS Architecture/Requirements instability
  - T&E environment complexities

Example: Single Integrated Air Picture

Single Integrated Air Picture – common, continuous, and unambiguous tracks of airborne objects... reduce the risk of fratricide and counter emerging threats

Operational Architecture

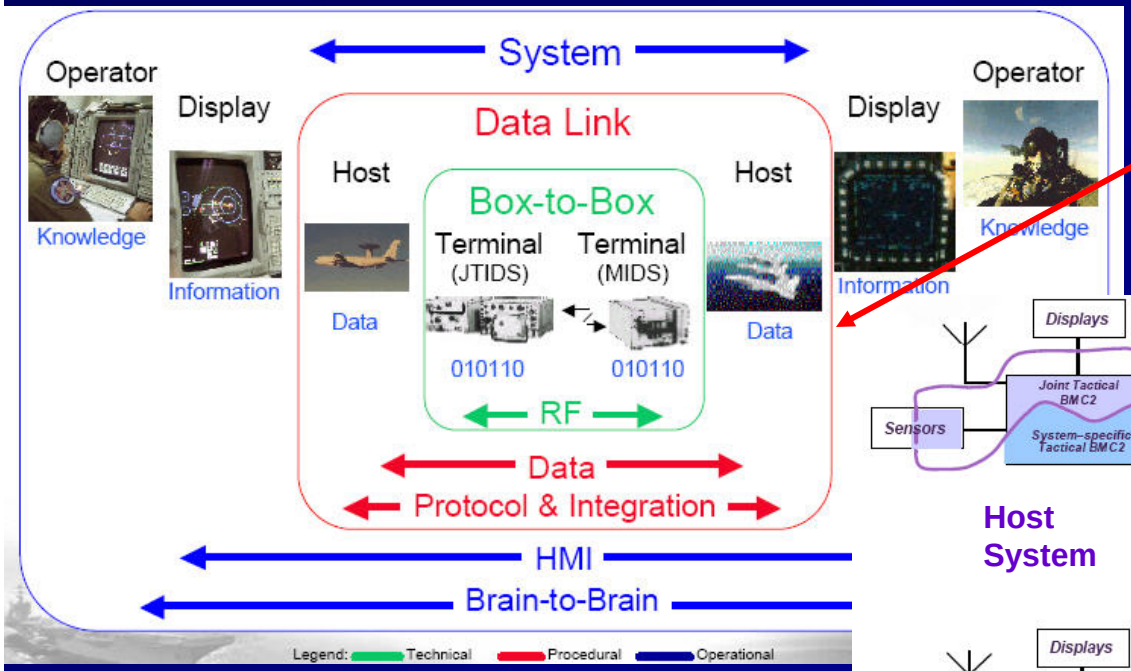
- KPPs specified for SoS
- Common Distributed Processing - Multiple systems developing shared awareness to support collaborative operations

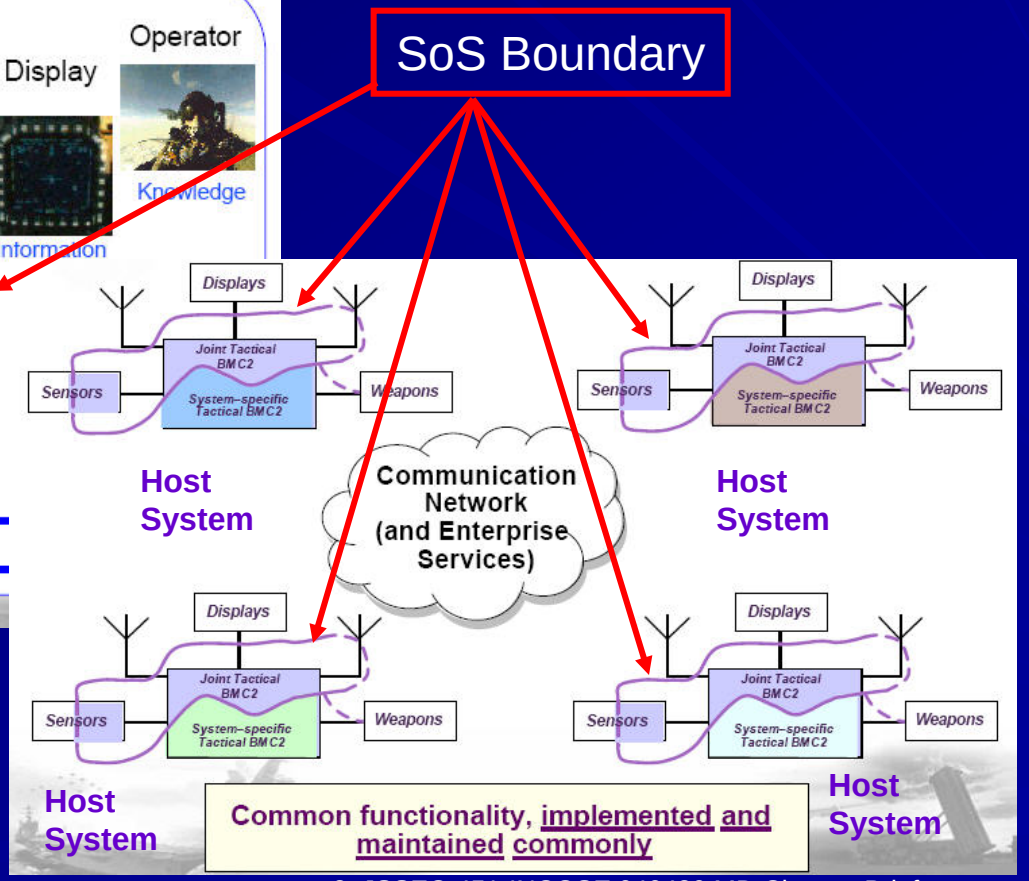
8. JSSEO 451-INCOSE 040430 MD Chapter Brief

Example: Single Integrated Air Picture

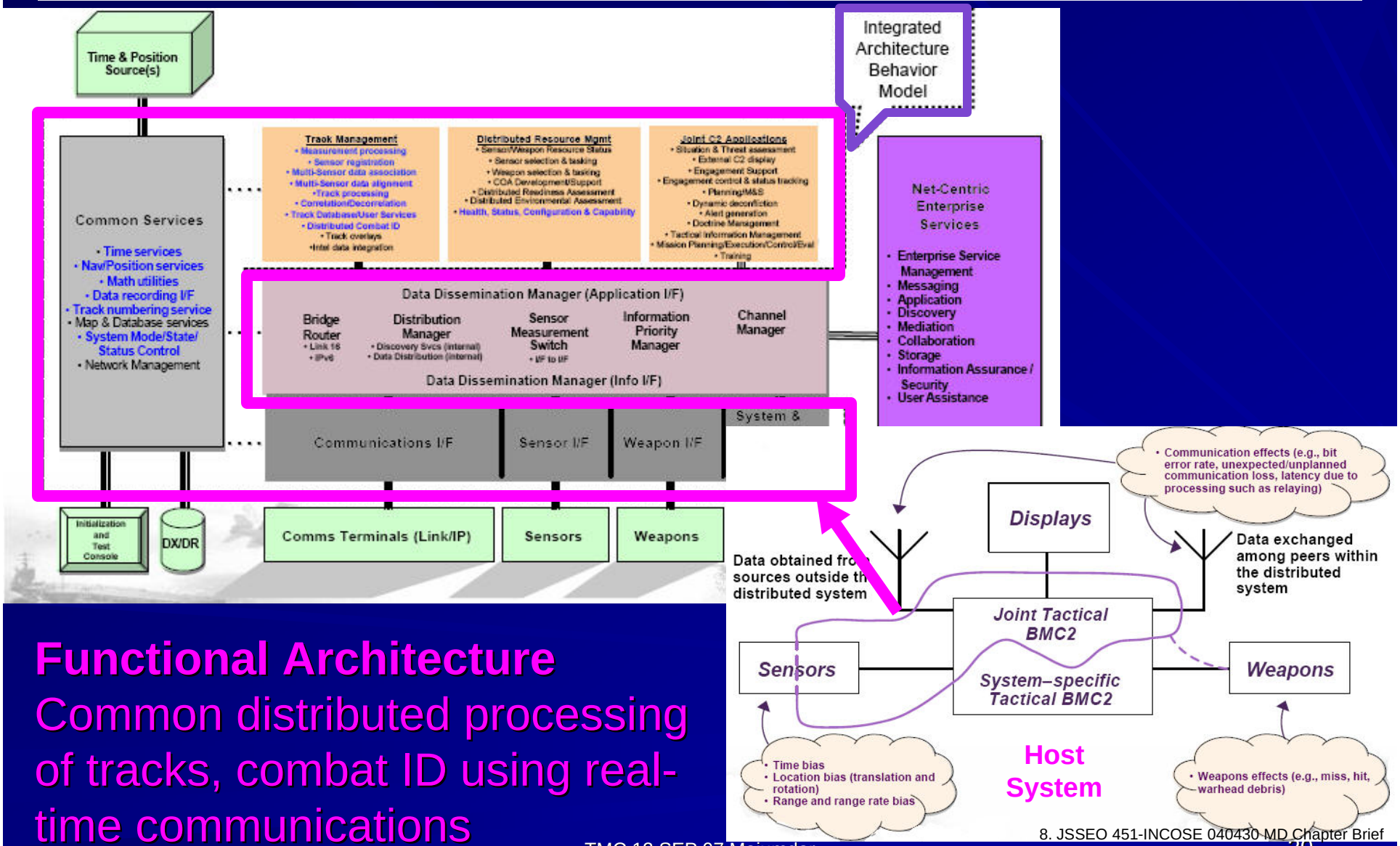
SoS Architecture

- KPPs measured at the SoS boundary





Example: Single Integrated Air Picture

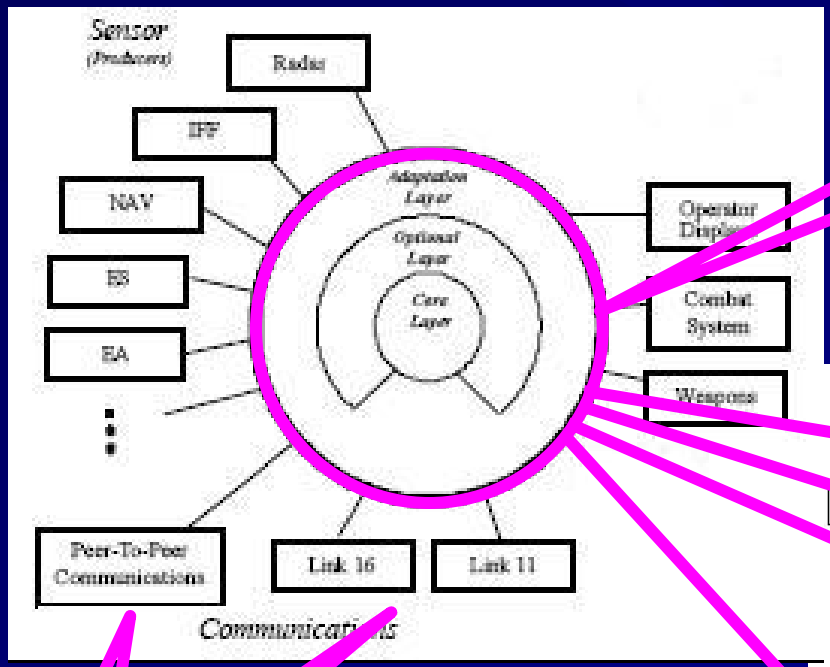


Functional Architecture

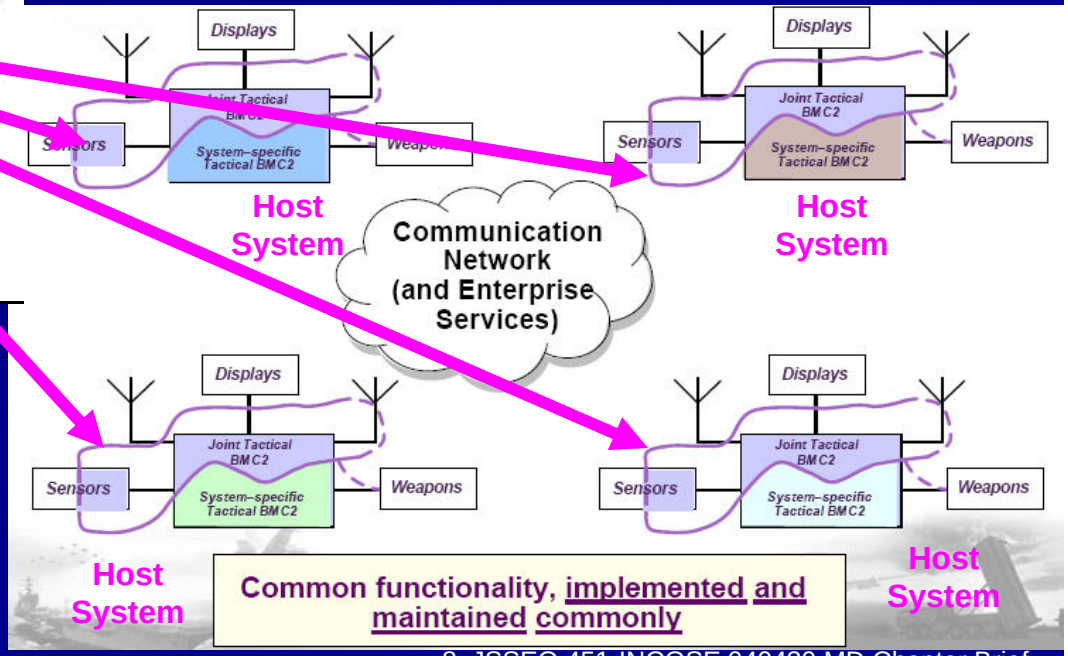
Common distributed processing of tracks, combat ID using real-time communications

Example: Single Integrated Air Picture

Critical Technology Elements



Track – common algorithms and exchange of data
CID – common methods and exchange of data



Host Communications – synchronized real-time, message processing

Example: Single Integrated Air Picture

Technical Readiness Assessment

- KPPs specified for SoS; boundary specified at OV/SV levels
- Type of SoS: Common Distributed Processing
- Identified multiple critical technologies to support CDP
  - Host and IABM Track – common processing
  - IABM CID – common processing
  - Host Communications – real-time, message processing
- Joint system and SoS testing required for TRL 6
  - Representative system technologies
- Joint Developmental Testing testing required for TRL 7
  - Common processing embedded with other combat system functions

Must track technologies for both SoS and Systems required to meet SoS KPPs

Example: Single Integrated Air Picture

Challenges

- Asynchronous system developments (priority, $, timelines)
- Legacy and new system elements
- Currently, SoS program MS B decision scheduled prior to system MS-Bs
  - System technologies not TRL 6 until system MS-B
- Anticipate that Legacy systems will mature at a faster rate and desire limited deployment decision for SIAP concurrent with their system IOC
  - No other system of the SoS is anticipated to have the same Initial Operating Capability date.

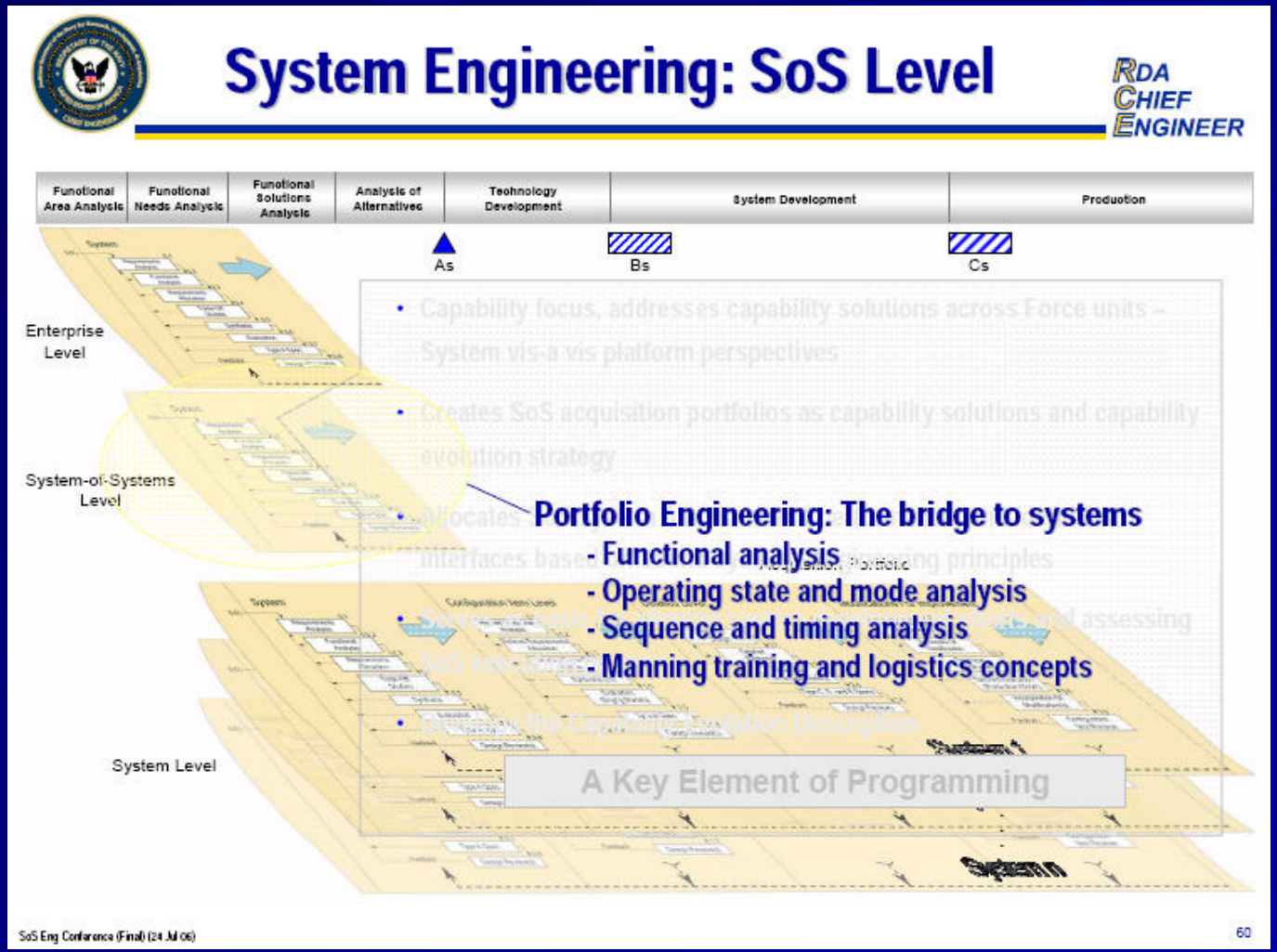
SoS – Here to Stay

System ⊄ SoS

- **Degree of interoperability; Capability specified at SoS boundary**
- **Long term SoS developments; SoS Engineering up front**
- **SoS acquisition milestone decisions;**
  - **Requirements decisions prior to system decisions**
  - **Maturation activities lag system activities**
- **SoS Technologies**
  - **Technology development and selections made by the SoS and System Program Managers**
  - **SoS Maturation demonstration collaborative effort**

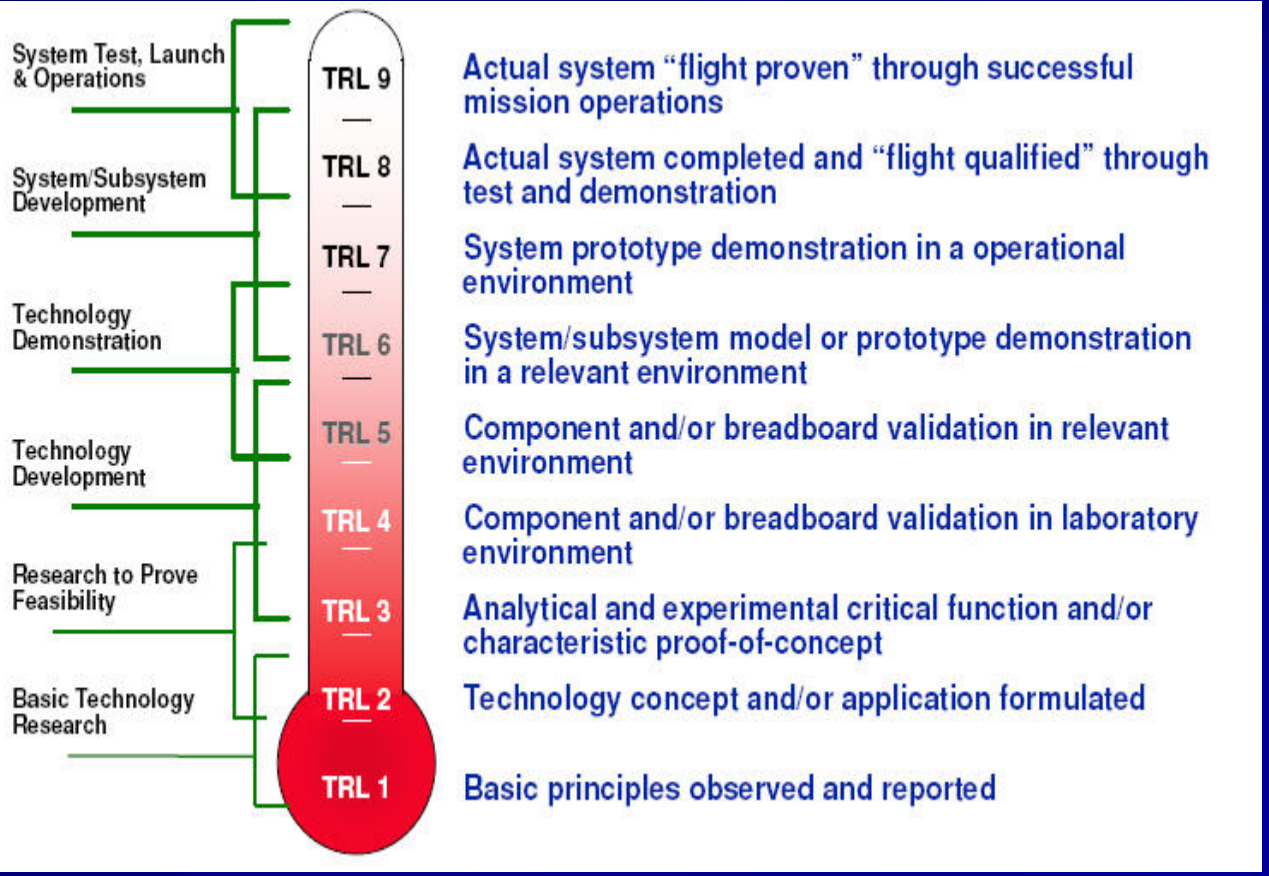
SoS Portfolio Management

DoD Guidance needed for SoS acquisitions



SoS TRLs

Add the following SoS TRL scale descriptions



TRL 9 Actual SoS…

TRL 8 Actual SoS

TRL 7 SoS prototype

TRL 6 SoS/System

TRL 5 relevant SoS

TRL 4 SoS environment

TRL 3 SoS proof – of - concept

SoS Way Ahead

DoD Guidance needed for SoS

- Definition of degrees of interoperability
- Portfolio management starts with SoS Engineering activities and technology development
  - Synchronization will be an ongoing challenge
- TRA Deskbook updates for SoS TRAs
- Guidance on '801 Certification'
  - Recommendation is to hold this for systems (not SoS)

Questions?

Thank you!

Bibliography

1. System of Systems Engineering Conference, ASN (RDA) Chief Engineer, 13 JUN 05
2. System of Systems Engineering Center of Excellence, 2nd Conference, Key Issues and Requirements in System of Systems for High-throughput Battlespace Information Fusion and Persistent Surveillance, Chris Powell, July 2006
3. Integrated Air and Missile Defense, Program Overview to Industry, 15 March 2007
4. Joint Chiefs of Staff Joint Publication 01-02 12 April 2001 as amended through 13 June 2007
5. Understanding Information Age Warfare, Alberts, Hayes and Signori, 2001, CCRP Publications
6. CJCSI 3170.01F 1 May 2007
7. Dickerson, C., & Soules, S. (2002). *Using architecture analysis for mission capability acquisition*
8. JSSEO 451-INCOSE 040430 MD Chapter Brief