Conceptual Modeling for an End-to-End C4ISR Systems Experiment Model

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Agenda

- Conceptual models as abstract representations
- UML as a conceptual modeling tool
- DoDAF as a framework for creating system architectures
- Mapping of UML to DoDAF
- Example application: FCS Experiment 1.1

Conceptual Modeling

A Definition: A representation of the most important concepts (and their relations) within a specific problem domain is called a conceptual model of the domain.

In order to create an efficient conceptual model of a domain you must be able to reduce its complexity.

Four important tools in complexity reduction are:

- Abstraction ⟷ disregard
- Hierarchy ⟷ resolution
- Encapsulation ⟷ interface
- Modularity ⟷ partition

UML as a Conceptual Modeling Tool

- The UML is the Unified Modeling Language
- The UML represents a unification of the concepts and notations of Booch, Rumbaugh, and Jacobson.
- The goal of the UML is to become a universal notation for creating models of object-oriented (OO) software.
- The UML is a modeling notation and does not prescribe a specific process.
- The UML is language-independent & vendor-independent.
- The UML can be used in conjunction with tools such as Visio, Rational Rose or TogetherJ.

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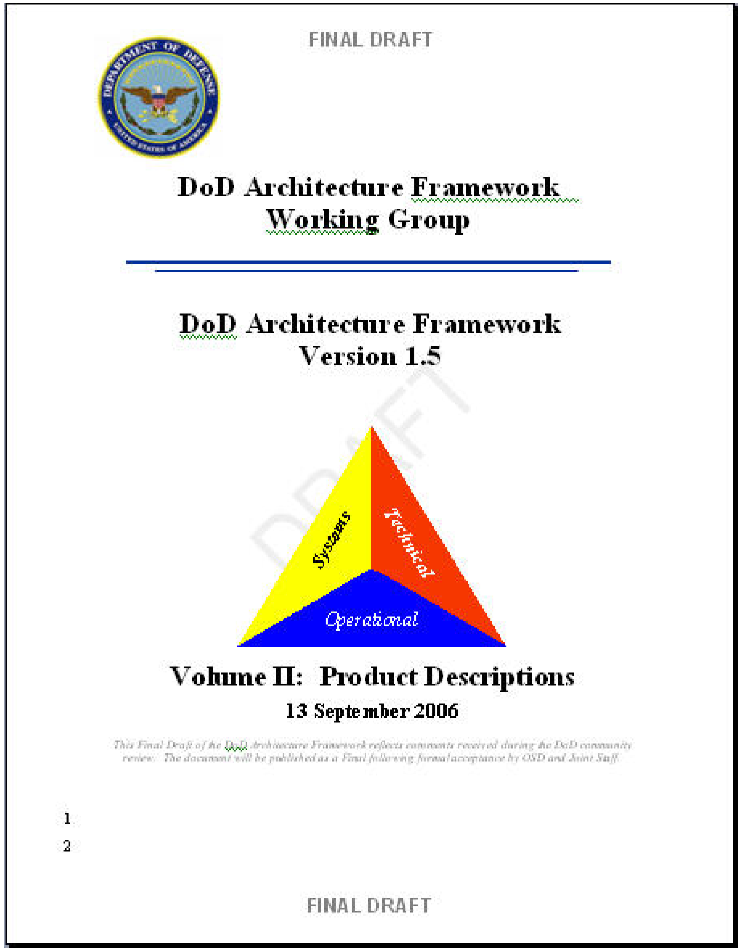
UML Diagrams

- Structural
  - Class diagrams: shows a set of classes, their relationships, and their interfaces
  - Object diagrams: Show a set of instances of classes and their relationships
  - Deployment diagrams: Show a static view of the physical components of the system
- Behavioral
  - Use case diagrams: Show interrelations among a set of use cases representing system functions
  - Sequence diagrams: Show messages passed among a set of objects in executing a system scenario
  - Collaboration diagrams: Model the same information as sequence diagrams, but configured more like class diagrams
  - State or state-chart diagrams: Model transition events and activities that change the system state
  - Activity diagrams: are flow charts of activities within a portion of the system

DoDAF

- DoDAF is the Department of Defense Architecture Framework.
- DoDAF consists of a set of Artifact Views.
- One can view DoDAF products, or at least the 3 views, as ANSI/IEEE 1471-2000 or ISO/IEC 42010 *viewpoints*.
- DoDAF views are organized into four basic view sets:
  - overarching All View (AV),
  - Operational View (OV),
  - Systems View (SV),
  - Technical Standards View (TV).
- Only a subset of the full DoDAF viewset is usually created for each system development.



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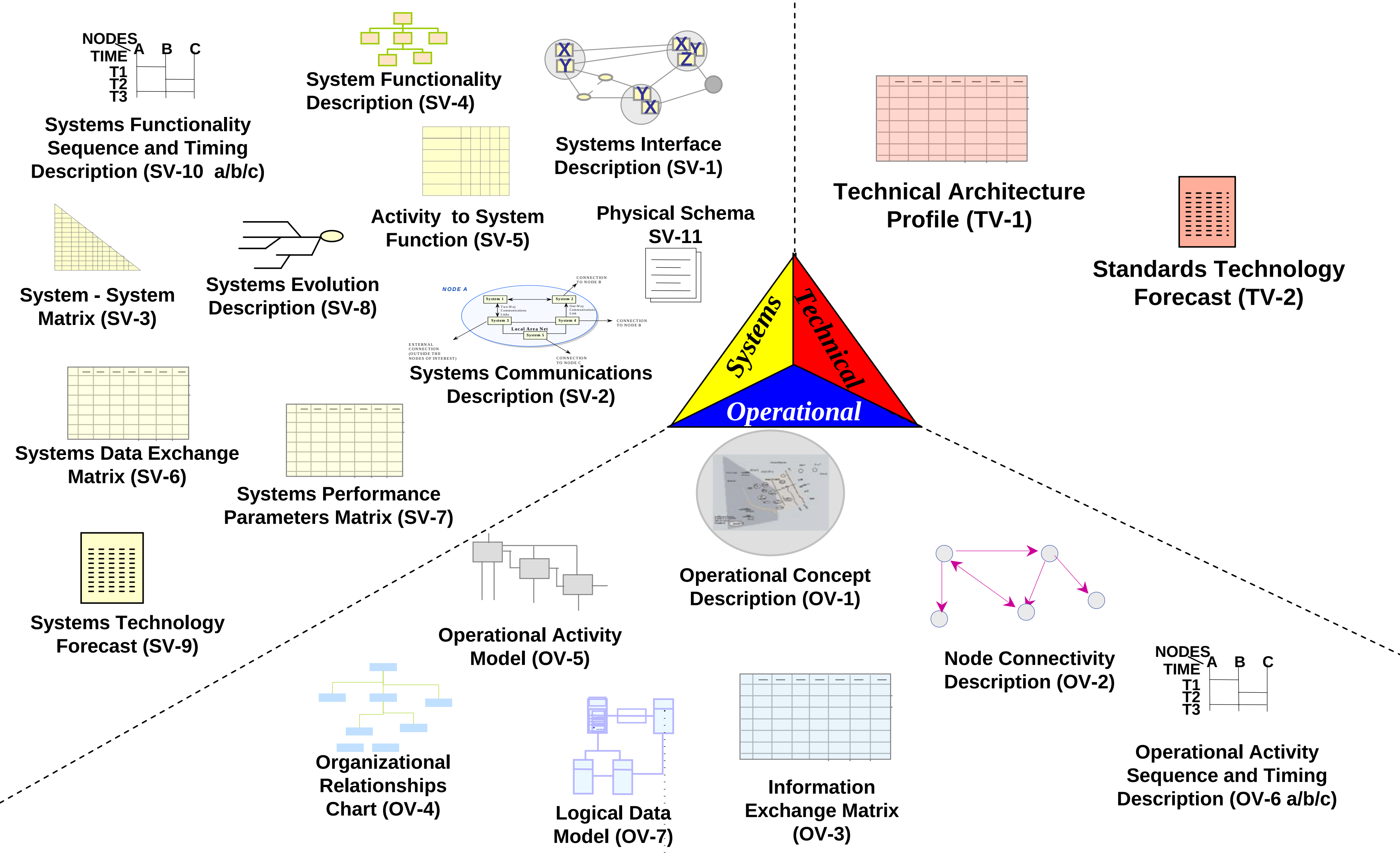
DoDAF overview

- DoDAF is the implementation chosen by the United States Department of Defense to gain compliance with the Clinger-Cohen Act and United States Office of Management and Budget Circulars A-11 and A-130.
- It is administered by the Undersecretary of Defense for Business Transformation's DoDAF Working Group.
- DoDAF was formerly named C4ISR AF.
- Other derivative frameworks based on DoDAF include:
  - NATO Architecture Framework (NAF)
  - Ministry of Defence (United Kingdom) AF (MODAF).

Representation

- Representations for the DoDAF products may be drawn from many diagramming techniques including: tables, ICAM Definition Language, Entity-Relationship Diagrams (ERDs), UML/ SysML, and other custom techniques depending on the product, tool used, and contractor/customer preferences.
- There is a UPDM (UML Profile for DoDAF and MODAF) effort within the OMG to standardize the representation of DoDAF products when UML is used (Released August 2007).
- DoDAF generically describes the representation of the artifacts to be generated, but allows considerable flexibility regarding the specific formats and modeling techniques.
- The DoDAF deskbook provides examples in using traditional systems engineering and data engineering techniques, and secondly, UML format.
- DoDAF proclaims latitude in work product format, without professing one diagramming technique over another.

Summary of DoDAF



Mapping of UML to Architecture Framework

	Description	Derived	Displayed in
OV-1	Operational Concept Graphic	Not Derived from any UML Diagram must be developed separately.	Class Diagram with Icons
OV-2	Operational Node Connectivity	Object Diagram showing the information diagram between nodes. Based on a Class Diagram with association classes.	Class Diagram or Collaboration Diagram
OV-3	Information Exchange Matrix	Derived from OV-2s and Activity Diagrams showing the information exchange between operational activities.	Excel
OV-4	Org Chart	Not normally developed in UML modeling, but the Class Diagram can be used to display the information.	Class Diagram
OV-5	Activity Model	Use the UML Activity Diagram with information exchanges on the arcs.	Activity Diagram for operational nodes, activities are the nodes operations.
OV-6a	Operational Rules Model	Can be autogenerated from a UML State Diagram	
OV-6b	State Transition	Use UML State Transition Diagram Directly	State Transition
OV-6c	Operational Events	Use UML Sequence Diagram Directly	Sequence Diagram
OV-7	Logical Data Model	Use the UML Class Diagram for Logical Data Modeling Directly	Class Diagram

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Mapping of UML to Architecture Framework

	Description	Derived	Displayed in
SV-1	System Interface	Use UML Class and Object Diagrams Can also use the Deployment Diagram for the high level.	Class Dgm
SV-2	Communications	Same as SV-1 but at lower level of detail	Class Dgm
SV-3	System-to-System Interface	Atuogenerated from the SV-1 and SV-2	Matrix
SV-4	System Functionality Description	Use Activity Diagrams same as OV-5 but with system rather than operational functions.	Activity
SV-5	System Functions to Operational Activities	Use Activity Diagrams same as OV-5 but with system rather than operational functions.	Activity
SV-6	System Data Exchange	Same as OV-3 but with system rather than operational functions.	Matrix
SV-7	System Performance Parameters	Knowledge outside of UML diagrams, [but can be captured in tagged value sets and the matrix generated from a script]	Matrix
SV-8	System Evolution	Knowledge outside of UML modeling, but the UML Class Diagram can be used to display the information.	Class Diagram
SV-9	System Technology Forecast	Outside of UML Domain [Class diagrams and tagged values can be used]	Word
SV-10		Same as OV-6 but at system rather than operational level	State & Sequence dgms
SV-11	Physical Data Model	Same as OV-7 but at the physical data model level.	Class diagram

Mapping of UML to Architecture Framework

	Description	Derived	Displayed in
TV-1	Technical Architecture Profile	Outside of UML Domain [Class diagrams and tagged values can be used]	Word
TV-2	Technical Standards Forecast	Exclusive of UML modeling	Word
AV-1	Overview and Summary Information	Exclusive of UML modeling	Word
AV-2	Integrated Dictionary	Generated from the UML model, all diagrams.	TBD

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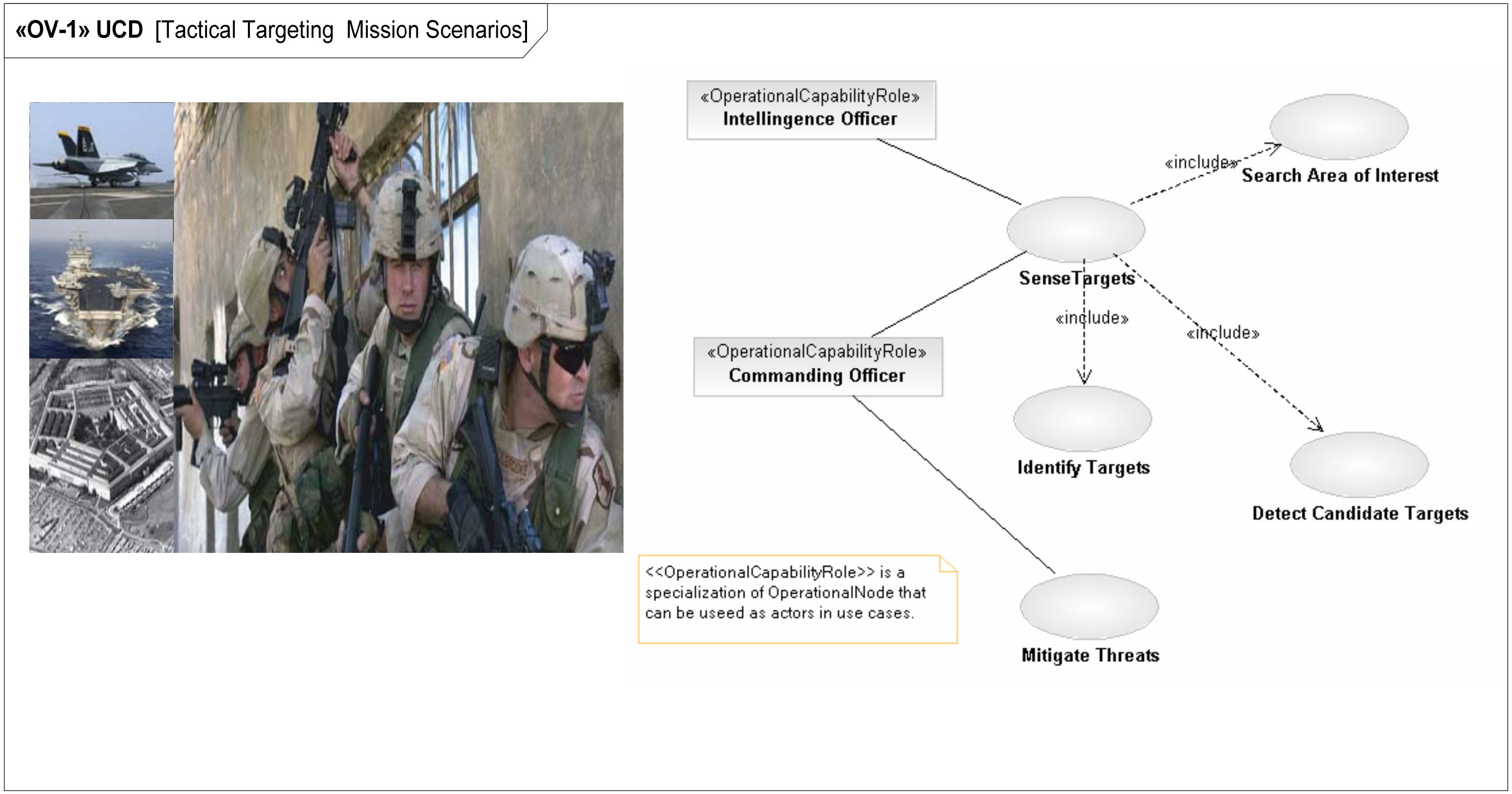
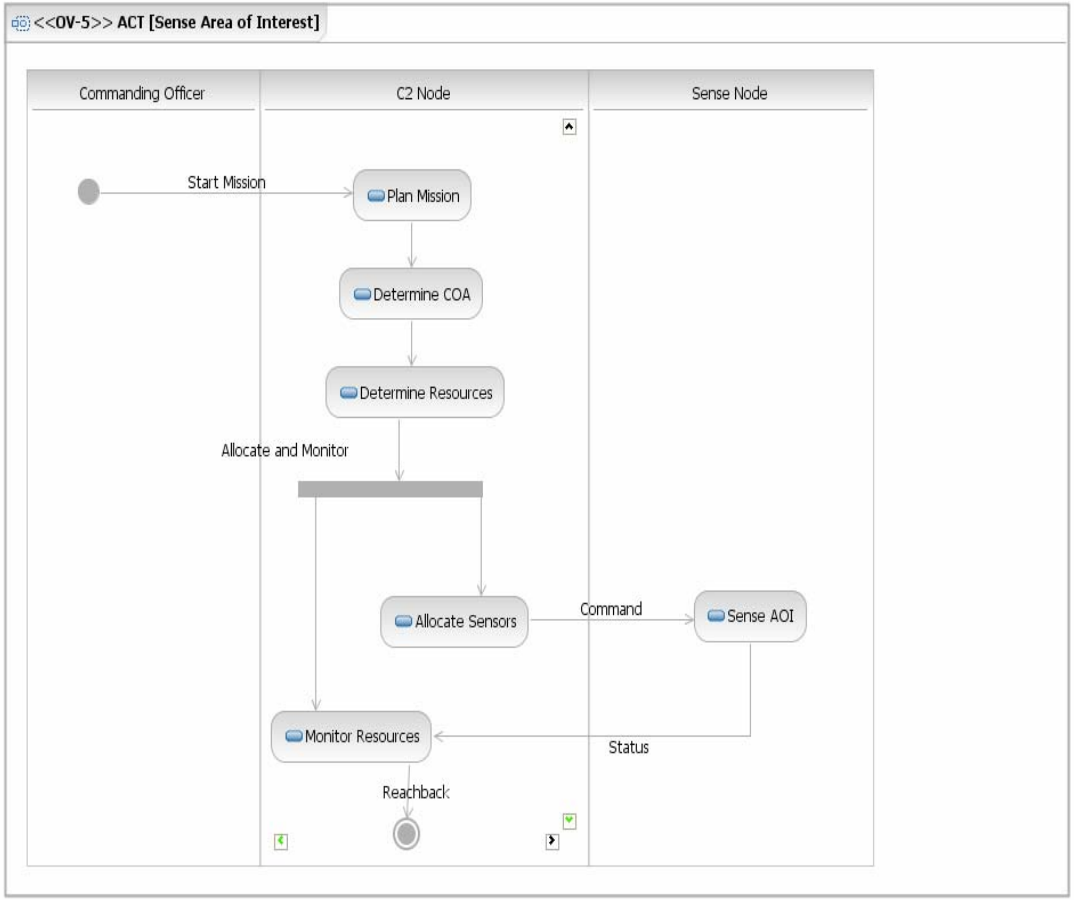
OV-1 Representation



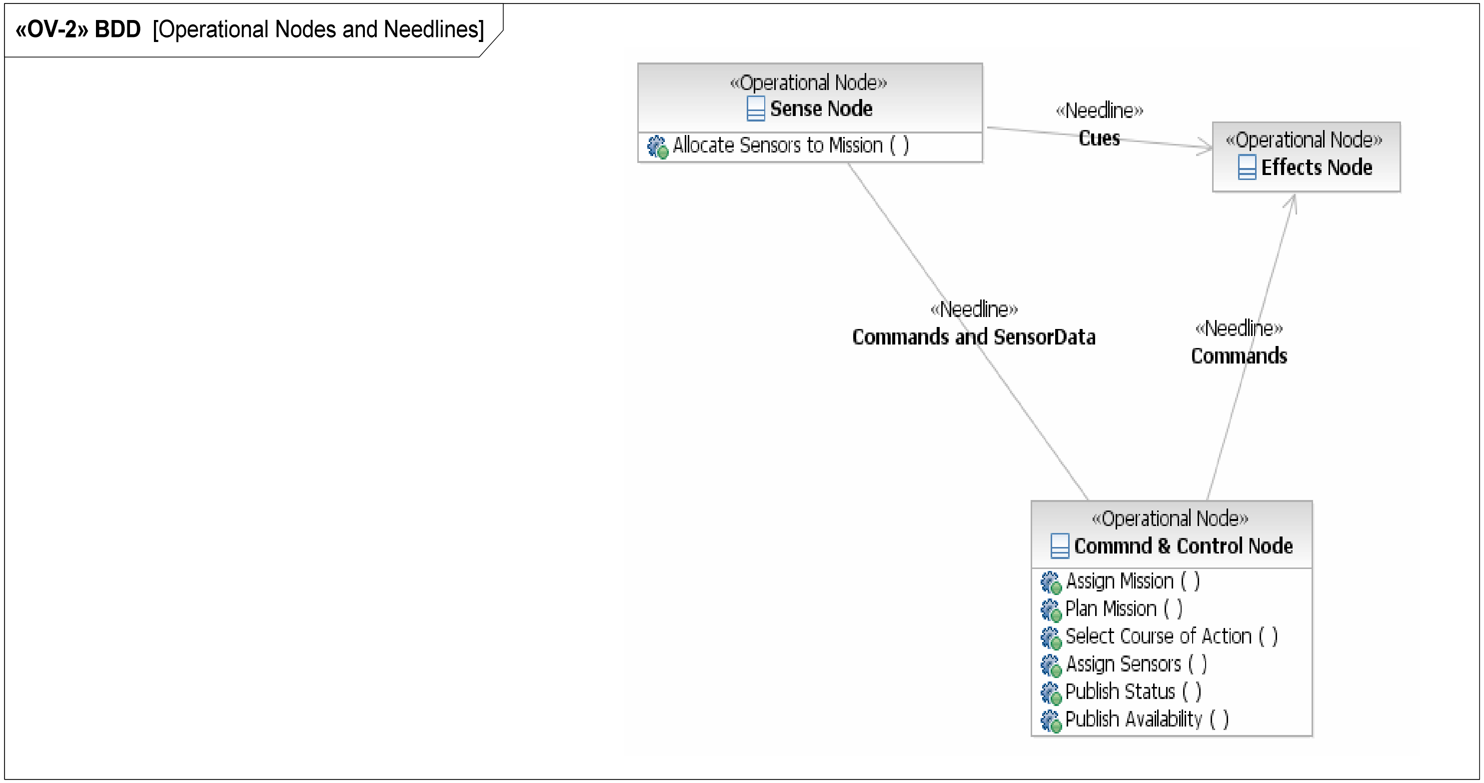
OV-1 Captures the Operational Context graphically and as Role and Use Case models representing Mission Context, Scenarios and enabling Capabilities (from UPDM)

OV-5 Representation



OV-5 Activity Diagram captures the behavior defined by OV-1 Use Cases via Operational Activities subsequently allocated to Operational Nodes (from UPDM)

OV-2 Representation



OV-2 Operational Nodes and Needlines as aggregations of allocated Operational Activities and Information Flows respectively (from UPDM)

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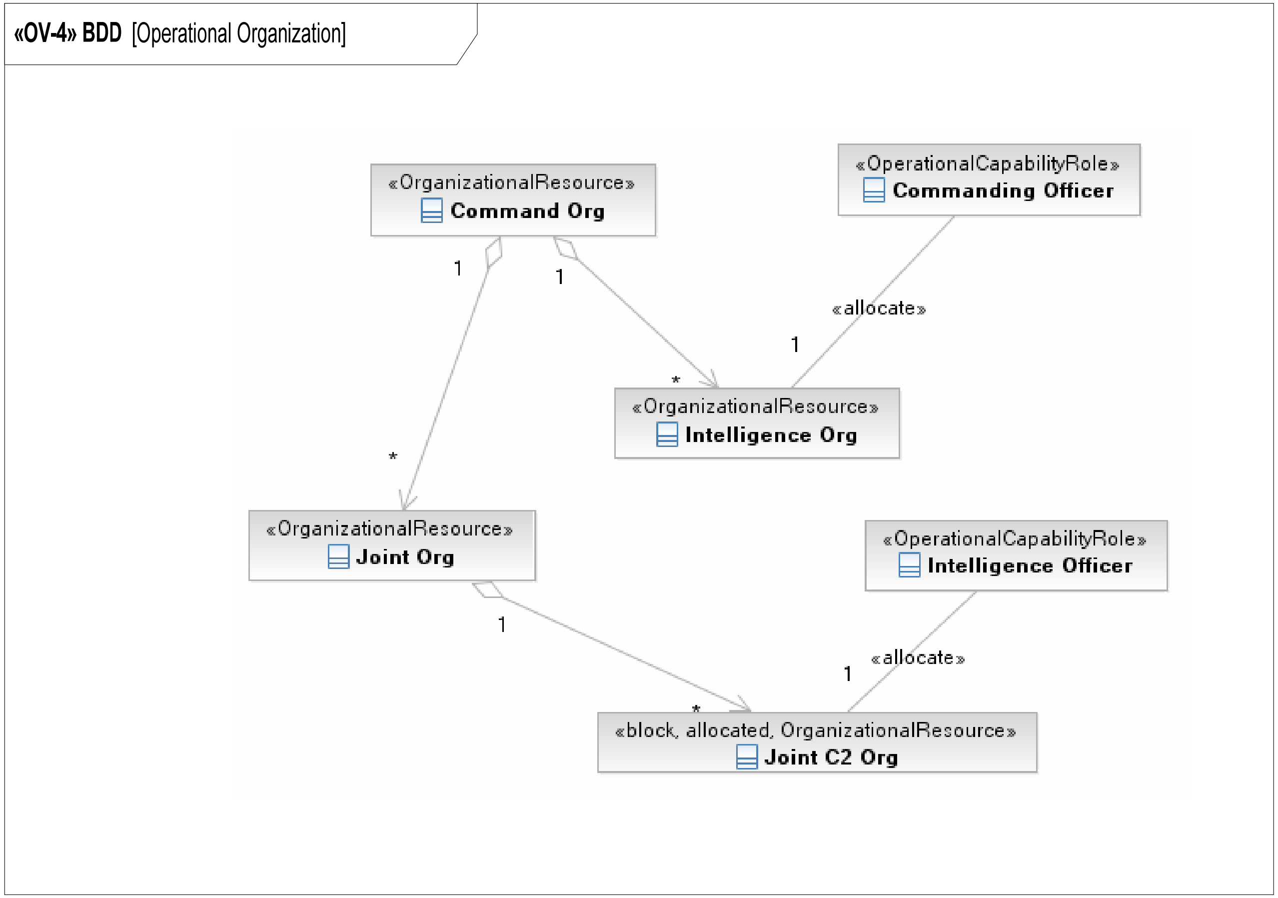
OV-3 Matrix Generation

«OV-3» Matrix [Information Exchange Matrix]

		Producer		Consumer	
Needline ID	Info Exchange ID	Sending Op Node	Sending Op Activty	Receiving Op Node	Receiving Op Activity
N1	IE1	Sense Node	Sense AOI	Effects Node	N/A
N2	IE2	Sense Node	Sense AOI	Command and Control Node	
N3	IE3	Command and Control Node	Allocate Sensors	Sense Node	Sense A
N4	IE4	Command and Control Node	N/A	Effects Node	N/A

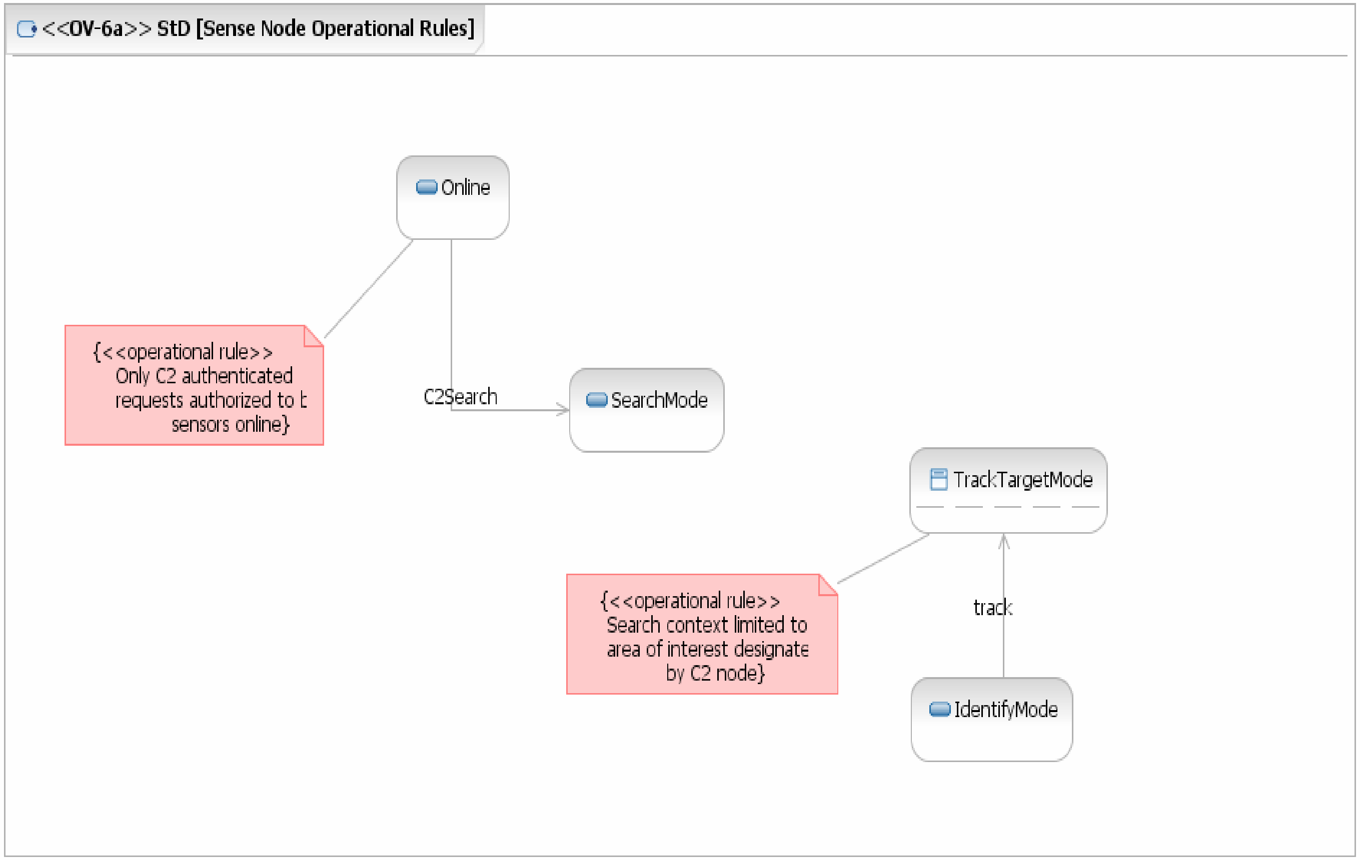
OV-3 Information Exchange Matrix auto generated based on Operational Activity Information Flows (from UPDM)

OV-4 Representation



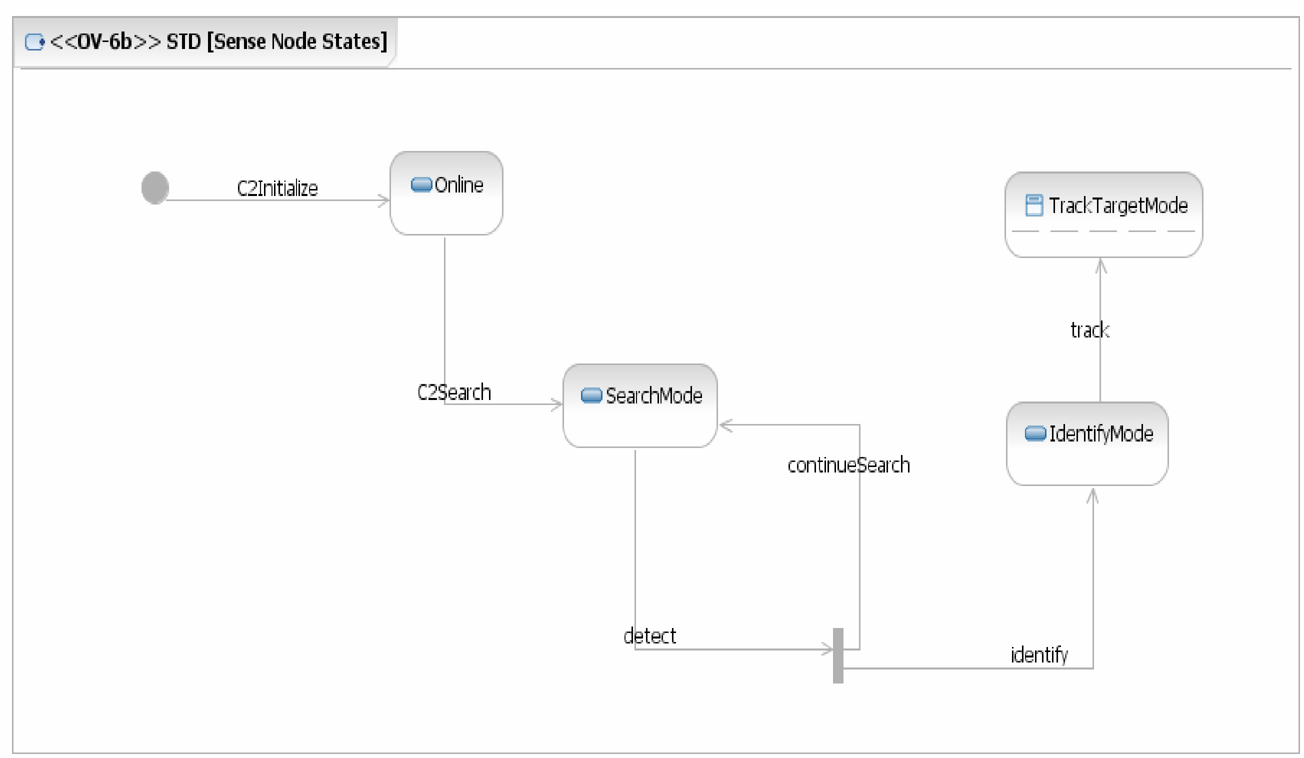
OV-4 Organizations and Roles allocated to each Organization are modeled by UML Composite Structure and SysML and Block Definition Diagrams (from UPDM)

OV-6a Representation



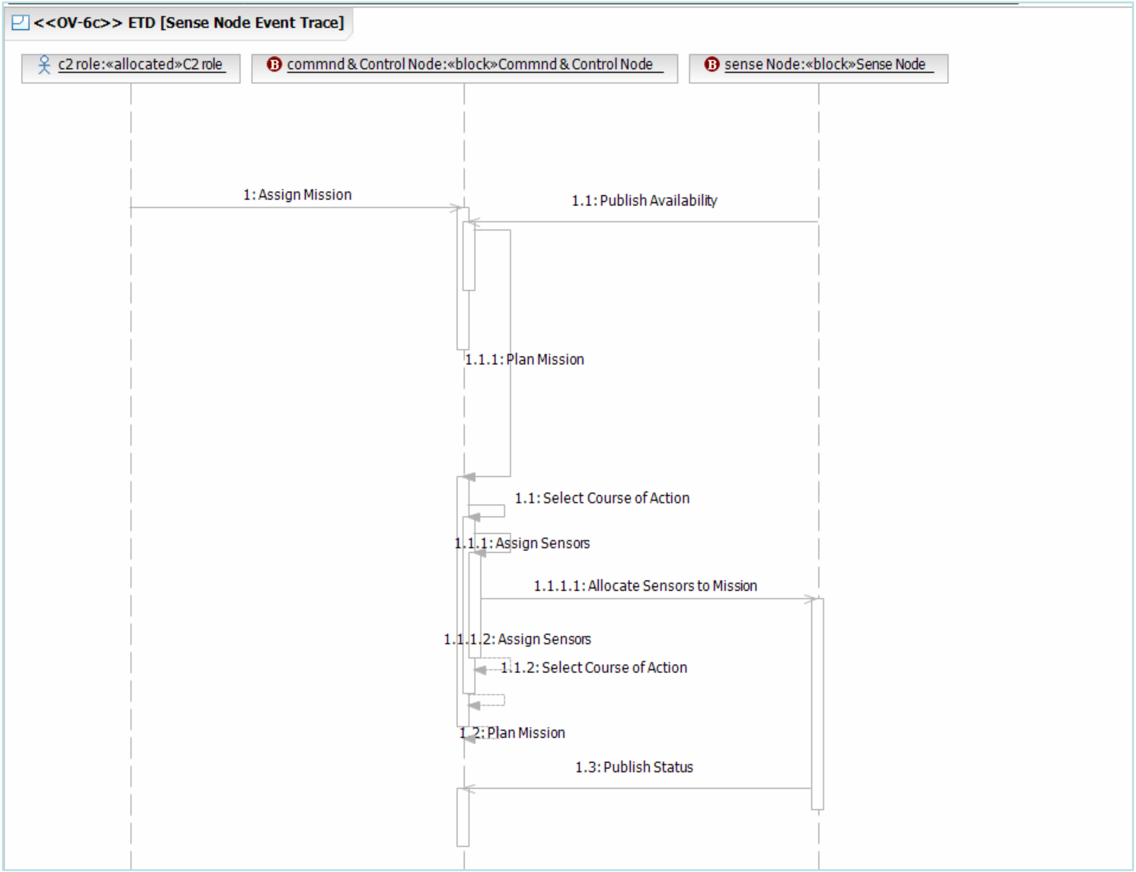
OV-6a Captures the Operational Rules allocated to Operational model elements including Nodes, Activities, Flows, Information Elements and States (from UPDM)

OV-6b Representation



OV-6b State Trace Diagram captures the Operational States and Transitions within Operational Nodes (from UPDM)

OV-6c Representation



OV-6c Event Trace diagram captures the event flow (messages) between instances of Operational Nodes…synchronized with Operational Activities allocated to Nodes (from UPDM)

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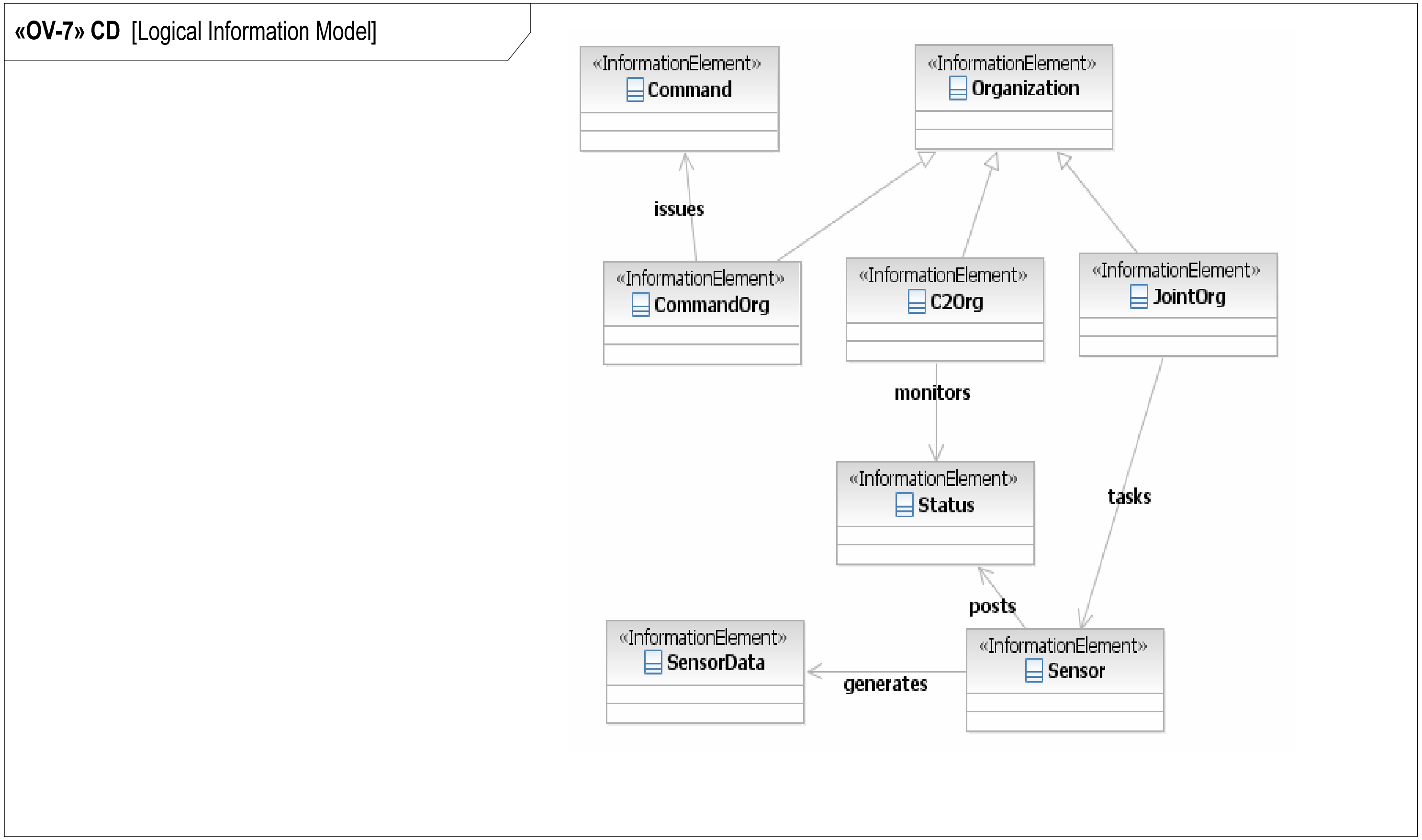
OV-7 Logical Information Model



OV-7 Defines Information Model for all Operational Information Flow elements identified within the integrated model and viewed via OV-3 and OV-5 (from UPDM)

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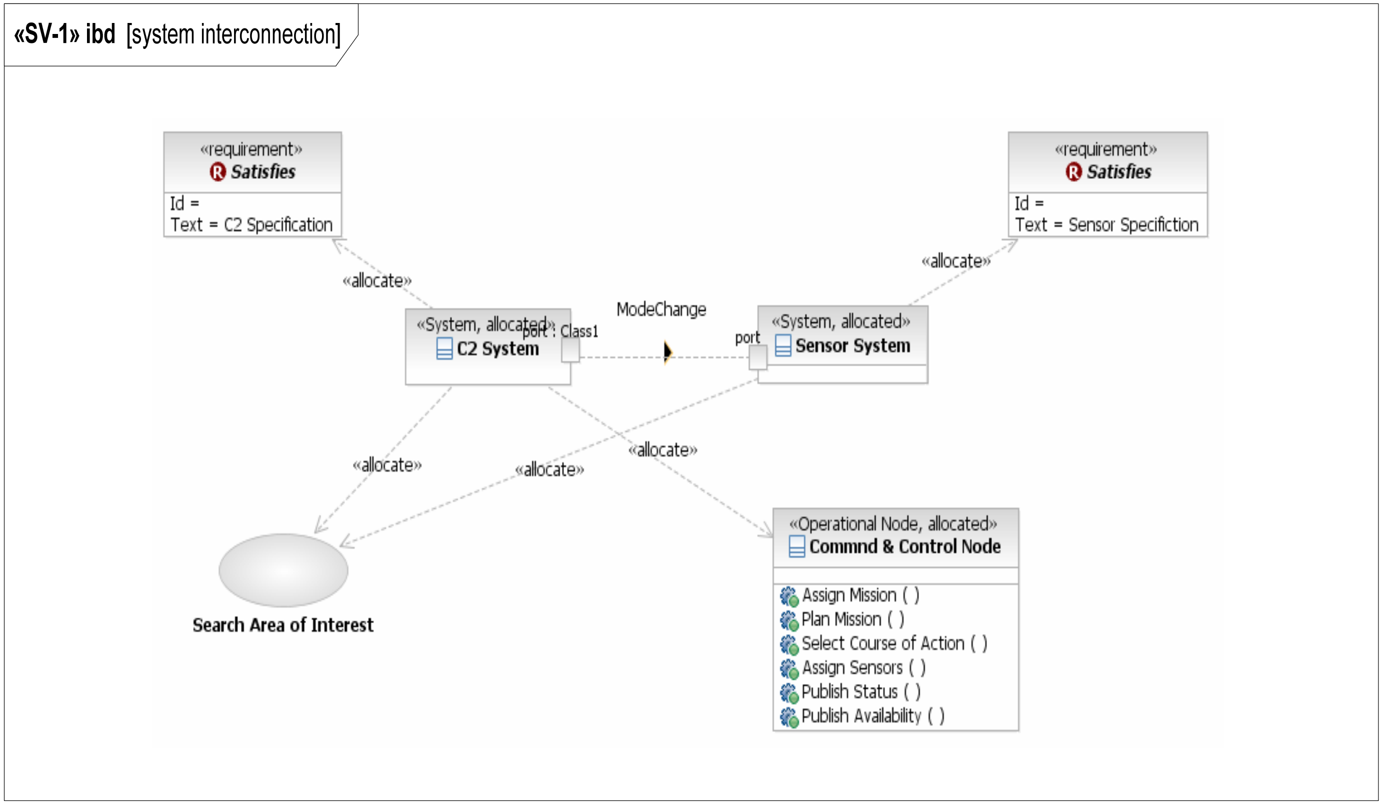
SV-1 Representation



SV-1 Provides the view of the Systems, their connections and data flows, and allocations to Mission Scenarios and Operational Activities (from UPDM)

Other Mappings

JME Foundation Model (JFM) Description, Alpha Version 1.3
Table 7-1: DoDAF Views Used in the Joint Mission Environment Foundation Model (JFM)

DoDAF View ID	DoDAF View Name	UML View	Application
AV-2	Integrated Dictionary	N/A	Dictionary of terms used in the JFM
OV-1	High-level Operational Concept	N/A	High-level description of the four (4) top-level JFM components
SV-4 Level 1	JFM Functional Decomposition Description: Level 1	UML Class Diagram	Define the relationships between the four top-level JFM components. This creates a high-level schema for semantic interactions within the entire JFM.
SV-4 Level 2	JFM Functional Decomposition: Level 2	UML Class Diagram	Captures the hierarchical structure (e.g. decomposition) of the JFM components.
SV-6	JFM Data Exchange Matrix	N/A	Identify the highest level of interactions and data exchange by the JFM components
SV-10c	JFM Event Trace Description	UML Sequence Diagram	Sequence diagrams that illustrate the activities of the JFM elements in relation to the JFM interactions
TV-1	Technical Standards Profile	N/A	Lists the technical standards and published guidelines for updating or using the JFM.

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Conceptual Modeling to Support ETE SPM For Testing and Experimentation

- Testing in and testing of a network environment is an immature and ill-defined concept and process.
- Network testing for FCS is further complicated by the absence or immaturity of real systems.
- In this environment it is important to understand how to design a test or experiment, using a combination of real, simulated, and surrogate systems, and be able to storyboard the results.
- This requires an end-to-end system process model that can be used to lay-out the experiment and predict the results.

How do we configure an experiment/test?
What do we test?
What do we test live vs. virtual?
What can we expect fro the experiment/test?

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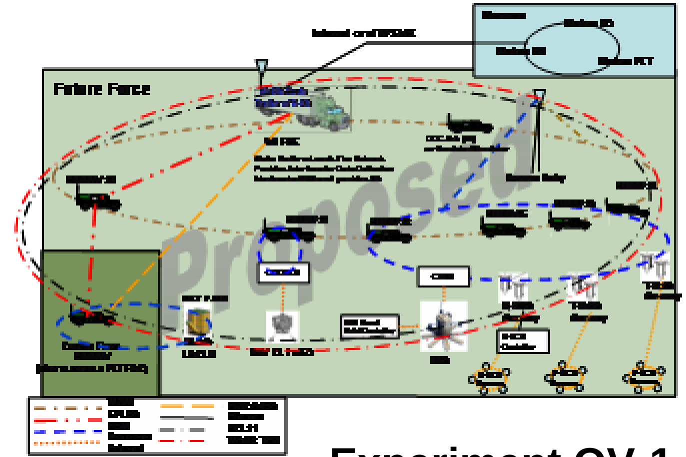
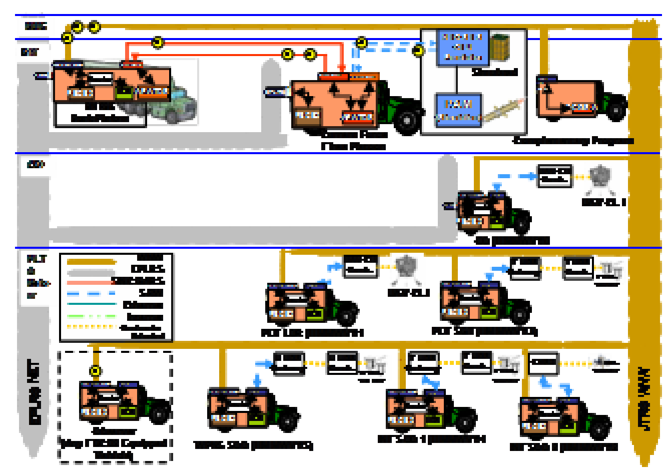
FCS Experiment 1.1

- EXP 1.1 provided an opportunity to assess the operations of the current systems (FBCB2), enhanced current systems planned for FCS Spin Out 1, and the future systems (FCS) in a battle space, quantifying performance as well as evaluating the ability to operate together.
- The FCS Program has instigated the experimentation process to
  - mitigate program risk
  - build system knowledge
  - provide feedback to SoS development, integration, etc.
  - to identify and prioritize needed changes early in the process.
- The EXP 1.1 objectives were:
  - Promote Joint/Coalition Interoperability
  - Provide data point for End-to-End Network Performance Analysis (using surrogates)
  - Inform the FCS Program of Record
  - Risk mitigation
  - Data Collection and Analysis to inform FCS SO1
- Mission Threads:
  - When ready fire mission
  - At my command fire order
  - Sensor detection red SA
  - Own position blue SA
  - Sensor location blue SA
  - Deactivate/activate IMS field



Experiment OV-1



Mission Thread OV-1

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End to End Thread Modeling: Prior Work

Measure SoS Performance In a Specified Operation Circumstance, e.g. Network Fires, With Discrete Event Simulation Model of the ETE Processes and *Behaviors*

- Operational Processes: Integrated Processes (Operation Will Entail Multiple Interrelated IPs
- SoS Architecture: Battle Command, SoSCOE Services, ISR Processes (Fusion; Video Arch.)
- Physical Platforms: Reside Within Geo Ref Grid; Movement; Spatial/Temporal Relationship to Other Battle Space Objects; Environments; Threats
- Math/Statistical Models of Capabilities and Functions (e.g. Sensor Detection, L1F)
- Connectivity Over Network: Capacity; SubNets; IP (Packet Formation and Routing); Message Type, Size and Content (In Some Cases Content is An Attribute, e.g Video Image); Background Traffic; Overhead
- ICS Model: Capacity Constrained

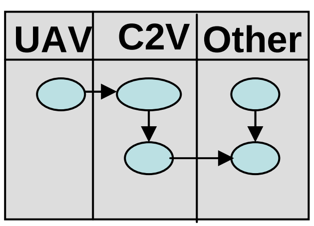
Operational Vignette

Requirements and MOPs

UML Activity Diagram of Modeled Process

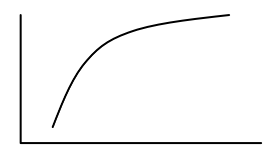
IPs

SoS Arch.



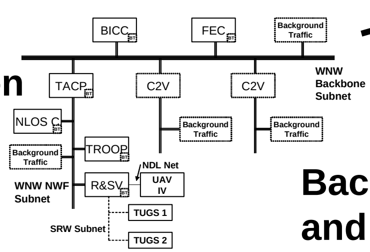
ETE SoS Performance (ESP) Model

ETE Performance



Requirement (Performance Parameter)

Network Definition



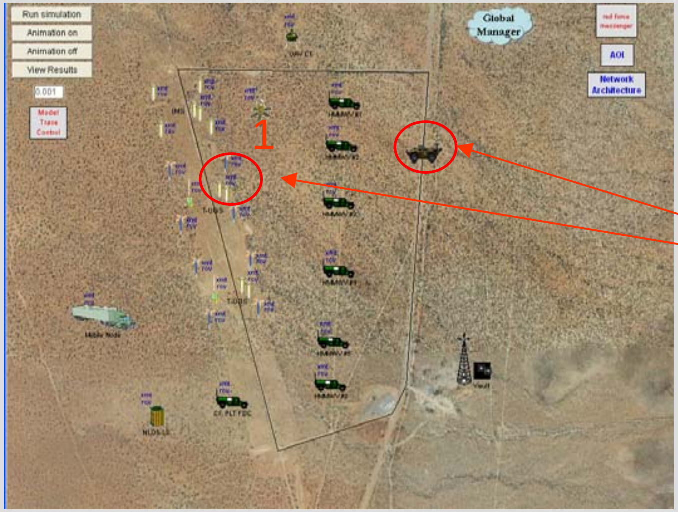
Background Traffic and Overhead

Platform Representations

Model Represents ETE Performance vs. Requirements Considering Resource Contention Under Work Load.

ESP Experiment Planning Tool

Scenario View



Operational Process View

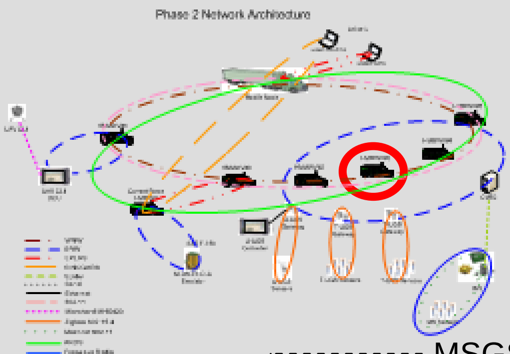
Key Events in the Operation
Highlighted Platform
Relative to the Operational Process?

1. Threat Detection Event
2. Track Report
3. Net Attack
4. Call for Fire
5. Etc.

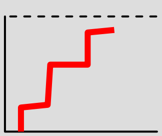
Network/QoS/IA Performance View

Network Utilization

Net 1



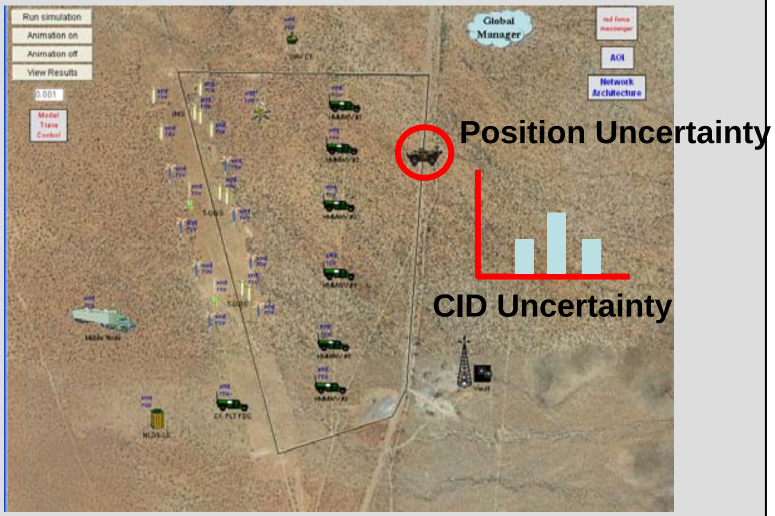
Queue
Length/Utilization



MSGS/
Priority
Xxx
Xxx
xxx

SLA Analysis: VOIP Rqmt vs Perf.

Sensor Fusion/COP Performance View



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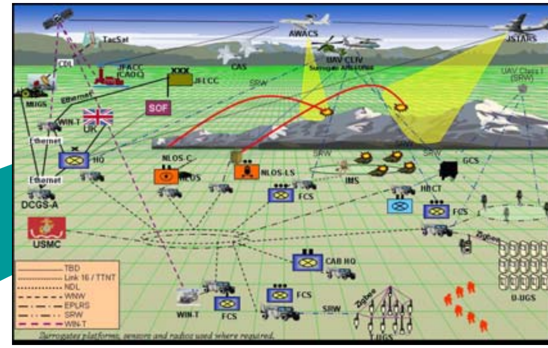
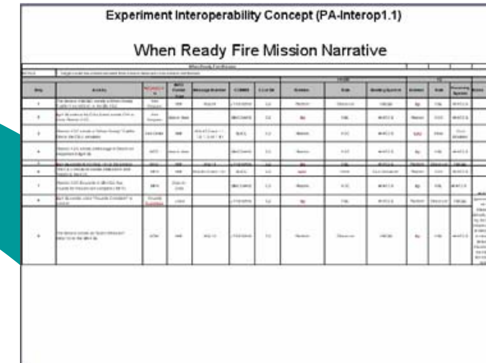
Exp 1.1 Conceptual Model Process

Exp 1.1 Documents



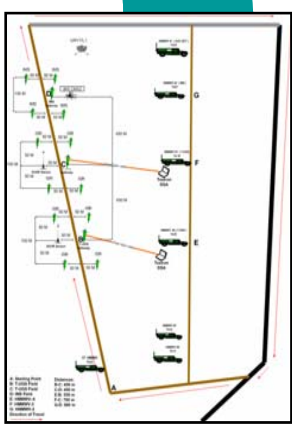
Exp 1.1 OV-1



Thread Documents

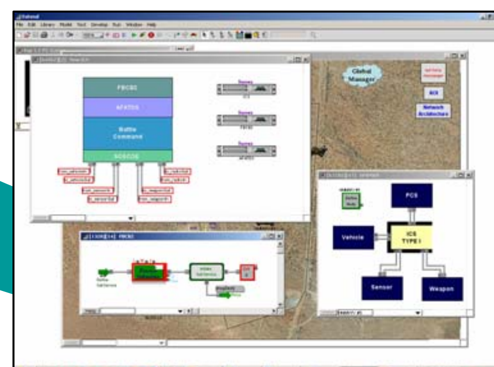
Iterative

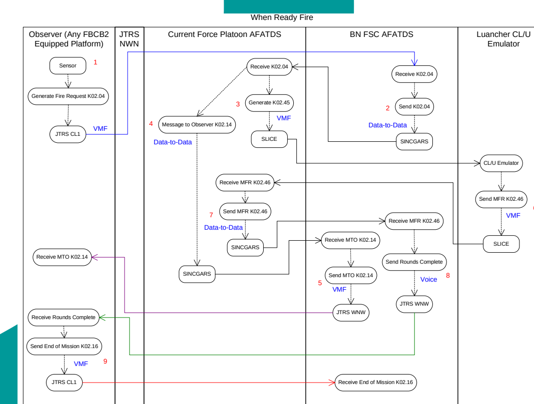
SME/Peer Reviews



Experimental Layout/Plan

ESP Model





SV-04 Activity Diagram

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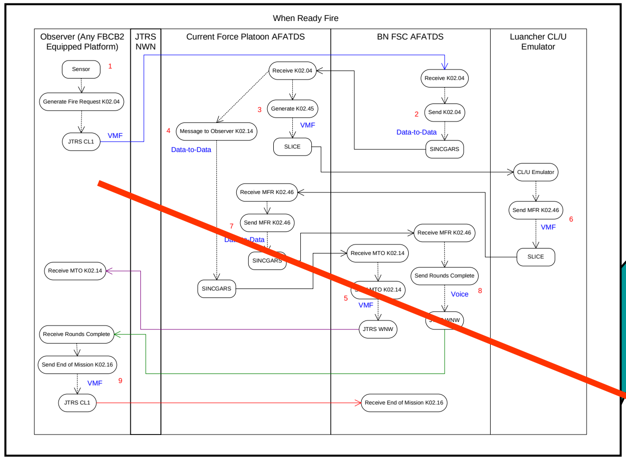
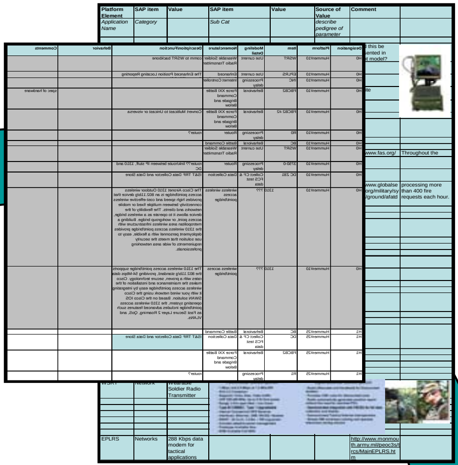
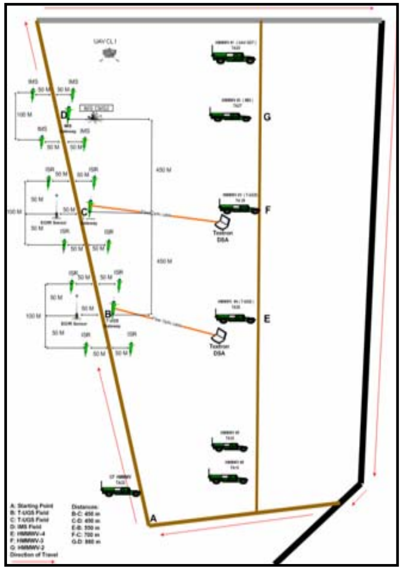
SPM Experiment Planning Tool Development Process



Conceptual Model

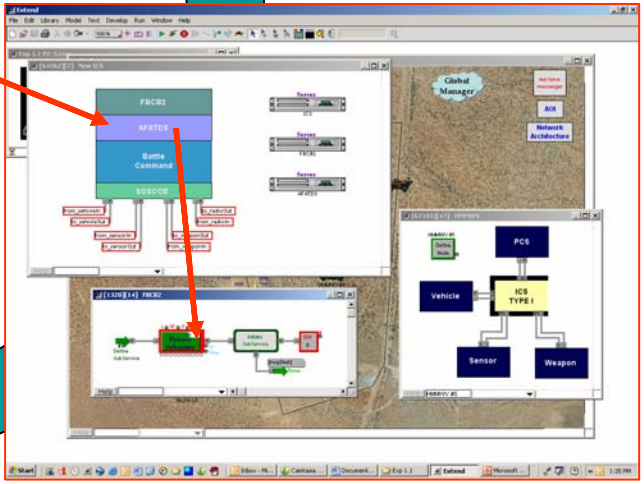


Analysis Parameters Notebook



Experimental Layout/Plan

Allocate Live and Virtual Test Articles, as well as Experiment Instrumentation



ETE ESP Model

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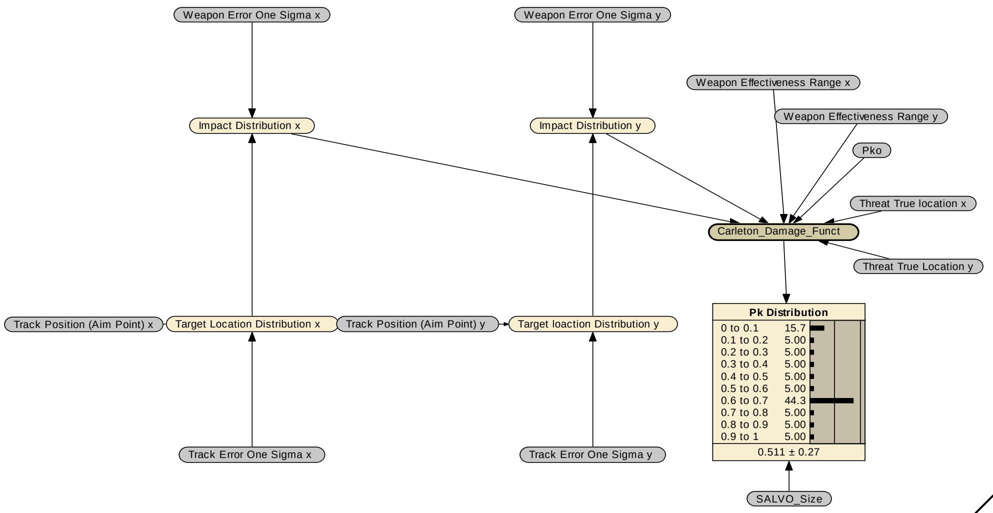
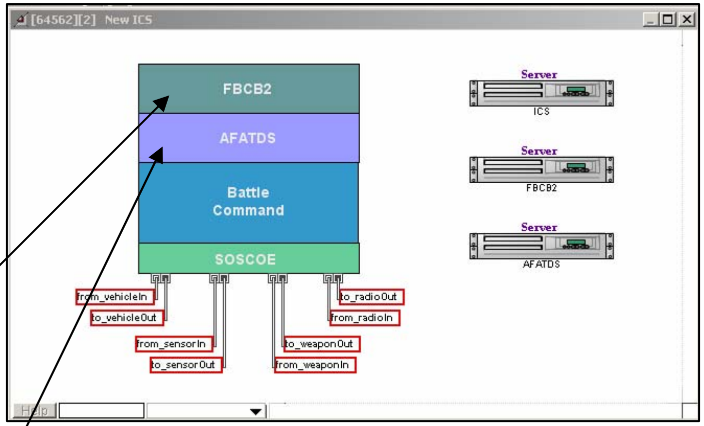
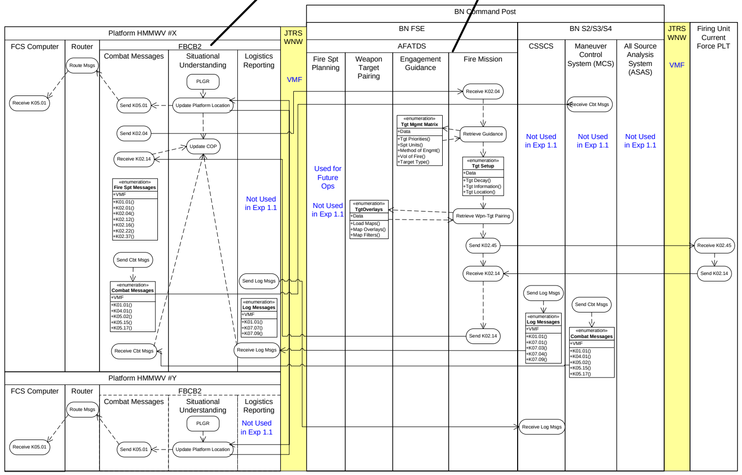
Other Conceptual Models



ETE SPM Submodel



Hybrid UML Diagrams



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Conclusions

CMSA

- Conceptual modeling facilitated the construction of model additions to the ETE SPM for test/experiment planning purposes.
- The DoDAF offered a use framework for developing various level of conceptual models for the ETE SPM Test Planning Tool
- UML provided a useful conceptual modeling language for some DoDAF views
- The ETE ESP was used successfully for planning experiments

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Acknowledgements

- Kent White, Chief Scientist, SPARTA, Inc.
- Jim Walsh, Chief Engineer, SPARTA, Inc.

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Backup

DoDAF overview

- DoDAF is organized around a shared repository to hold work products.
- The repository is defined by the Core Architecture Data Model 2.0 (CADM -- essentially a common database schema) and the DoD Architecture Repository System (DARS).
- A key feature of DoDAF is interoperability, which is organized as a series of levels, called Levels of Information System Interoperability (LISI).
- The developing system must not only meet its internal data needs but also those of the operational framework into which it is set.

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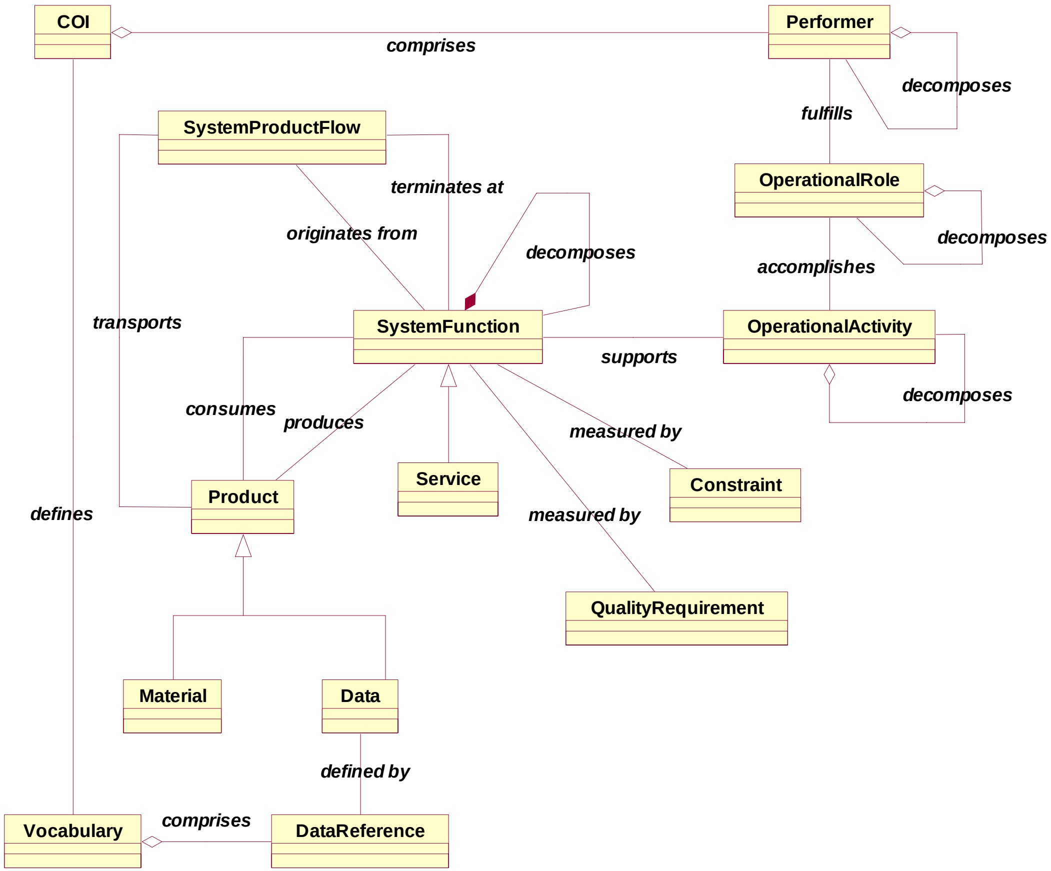
The Use of A Metamodel

- A metamodel is defined as 'a model that defines the components of a conceptual model, process, or system.'
- Underlying the 26 DoDAF products, there is an implicit metamodel that ensures that the DoDAF elements and relationships are defined consistently within and across the 26 DoDAF products as parts of a coherent structure.
- There are many benefits to creating and maintaining an explicit DoDAF metamodel following any standard conceptual modeling methodology:
  - Its creation reveals ambiguities and inconsistencies among current DoDAF elements and relationships will be revealed and will have to be resolved.
  - It can be used as a means to evolve and improve DoDAF consistently to support new architecture uses such as SOA.
  - It provides an overall picture of the common approach intended by DoDAF and enables the visualization of this overall picture and any portions of it (sub-views) as necessary.
  - Sub-views are usually intended to show portions of the overall picture with only the elements and relationships that are relevant to an aspect, usually corresponding to a DoDAF product.
  - With the visualization of an explicit DoDAF metamodel and its sub-views enabled, conceptual understanding of the common approach intended by DoDAF can be enhanced.

DODAF Metamodel Sub-View for SV-4



- Shows elements and relationships that support the interface-based characteristic of SOA.
- All interface related information of a service can be captured with attributes of and relationships to Service and is applicable to all potential consumers of the service.
- The same interface related information doesn't have to be duplicated for each additional consumer of the service.
- Shows DoDAF's current support for the capturing of a-priori data flows and added support for a-priori product flows.
- System product flows can be used to indicate pre-existing knowledge about flows of data or products between system functions.

All View (AV)

- AV products provide overarching descriptions of the entire architecture and define the scope and context of the architecture. The AV products are defined as:
  - **AV-1 Overview and Summary Information** - Scope, purpose, intended users, environment depicted, analytical findings (if applicable)
  - **AV-2 Integrated Dictionary** - Definitions of all terms used in all products.

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Operational View (OV)

- OV products provide descriptions of the tasks and activities, operational elements, and information exchanges required to accomplish DoD missions.
- The OV provides textual and graphical representations of operational nodes and elements, assigned tasks and activities, and information flows between nodes.
- It defines the type of information exchanged, the frequency of exchanges, the tasks and activities supported by these exchanges and the nature of the exchanges

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The OV products

- **OV-1 High Level Operational Concept Graphic** - High level graphical and textual description of operational concept (high level organizations, missions, geographic configuration, connectivity, etc).
- **OV-2 Operational Node Connectivity Description** - Operational nodes, activities performed at each node, and connectivites and information flow between nodes.
- **OV-3 Operational Information Exchange Matrix** - Information exchanged between nodes and the relevant attributes of that exchange such as media, quality, quantity, and the level of interoperability required.
- **OV-4 Organizational Relationships Chart** - Command, control, coordination, and other relationships among organizations.
- **OV-5 Operational Activity Model** - Activities, relationships among activities, inputs and outputs. In addition, overlays can show cost, performing nodes, or other pertinent information.
- **OV-6a Operational Rules Model** - One of the three products used to describe operational activity sequence and timing that identifies the business rules that constrain the operation.
- **OV-6b Operational State Transition Description** - One of the three products used to describe operational activity sequence and timing that identifies responses of a business process to events.
- **OV-6c Operational Event-Trace Description** - One of the three products used to describe operational activity sequence and timing that traces the actions in a scenario or critical sequence of events.
- **OV-7 Logical Data Model** - Documentation of the data requirements and structural business process rules of the Operational View.

Systems View (SV)

- SV products provide graphical and textual descriptions of systems and system interconnections that provide or support DoD functions.
- Interconnections between systems defined in the OV are described in the SVs.

Releasable to the public.

The SV products

- **SV-1 System Interface Description** - Identification of systems and system components and their interfaces, within and between nodes.
- **SV-2 Systems Communications Description** - Physical nodes and their related communications lay downs.
- **SV-3 Systems-Systems Matrix** - Relationships among systems in a given architecture. It can be designed to show relationships of interest, e.g., system-type interfaces, planned existing interfaces, etc.
- **SV-4 Systems Functionality Description** - Functions performed by systems and the information flow among system functions.
- **SV-5 Operational Activity to Systems Functionality Traceability Matrix** - Mapping of system functions back to operational activities.
- **SV-6 Systems Data Exchange Matrix** - Detailing of data exchanges among system elements and applications allocated to system elements.
- **SV-7 Systems Performance Parameters Matrix** - Performance Characteristics of each system's hardware and software elements, for the appropriate timframes.

The SV products

- **SV-8 Systems Evolution Description** - Planned incremental steps toward migrating a suite of systems to a more efficient suite, or toward evolving a current system to a future implementation.
- **SV-9 Systems Technology Forecast** - Emerging technologies and software and hardware products that are expected to be available in a given set of timeframes, and that will affect future development of the architecture.
- **SV-10a Systems Rules Model** - One of three products used to describe systems activity sequence and timing -- Constraints that are imposed on systems functionality due to some aspect of systems design or implementation.
- **SV-10b Systems State Transition Description** - One of three products used to describe systems activity sequence and timing -- Responses of a system to events.
- **SV-10c Systems Event-Trace Description** - One of three products used to describe systems activity sequence and timing -- System specific refinements of critical sequences of events described in the operational view.
- **SV-11 Physical Schema** - Physical implementation of the information of the Logical Data Model, e.g., message formats, file structures, and physical schema.

Releasable to the public.

Technical Standards View (TV)

- TV products define technical standards, implementation conventions, business rules and criteria that govern the architecture. The TV products are as follows:
- **TV-1 Technical Standards Profile** - Extraction of standards that applies to the given architecture.
- **TV-2 Technical Standards Forecast** - Description of emerging standards that are expected to apply to the given architecture, within an appropriate set of timeframes.

Releasable to the public.