Systems Engineering for the Joint Capabilities Integration and Development System (JCIDS)

Tutorial for the 9th NDIA Systems Engineering Conference

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

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The Johns Hopkins University
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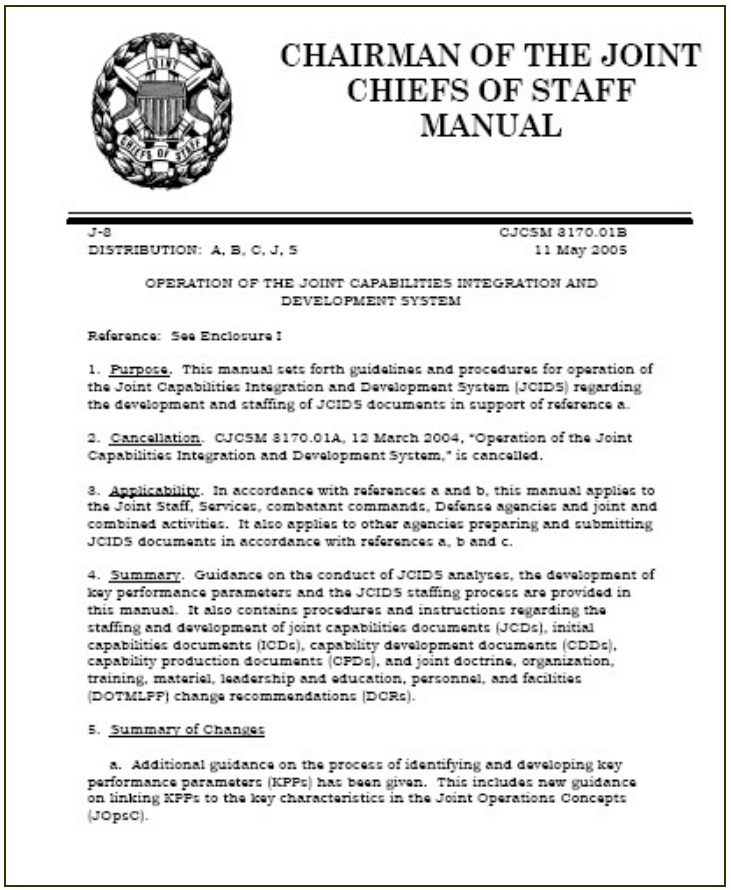
Agenda and Presenters

- Introduction to JCIDS – Chris Ryder
- Applying the Systems Engineering Method for JCIDS – Dave Flanigan
- Model-Driven Systems Engineering for JCIDS – Jennifer Rainey
- JCIDS Functional Analyses – Dave Krueger and Chris Ryder
- Summary – Chris Ryder

Purpose of the Tutorial

- JCIDS prescribes a joint forces approach to identify capability gaps against current force capability needs
- The Systems Engineering (SE) Method applies to each iteration of the systems life-cycle from capability inception through system retirement
- Good systems engineering practice is necessary for successfully implementing JCIDS
- JCIDS Functional Analyses perform critical problem solving activities
- Use of model-driven SE facilitates JCIDS throughout the systems life-cycle

What is JCIDS?



CHAIRMAN OF THE JOINT CHIEFS OF STAFF MANUAL

J-8 CJCSM 3170.01B
DISTRIBUTION: A, B, C, J, S 11 May 2005

OPERATION OF THE JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM

Reference: See Enclosure I

1. Purpose. This manual sets forth guidelines and procedures for operation of the Joint Capabilities Integration and Development System (JCIDS) regarding the development and staffing of JCIDS documents in support of reference a.

2. Cancellation. CJCSM 3170.01A, 12 March 2004, "Operation of the Joint Capabilities Integration and Development System," is cancelled.

3. Applicability. In accordance with references a and b, this manual applies to the Joint Staff, Services, combatant commands, Defense agencies and joint and combined activities. It also applies to other agencies preparing and submitting JCIDS documents in accordance with references a, b and c.

4. Summary. Guidance on the conduct of JCIDS analyses, the development of key performance parameters and the JCIDS staffing process are provided in this manual. It also contains procedures and instructions regarding the staffing and development of joint capabilities documents (JCDs), initial capabilities documents (ICDs), capability development documents (CDDs), capability production documents (CPDs), and joint doctrine, organization, training, material, leadership and education, personnel, and facilities (DOTMLPF) change recommendations (DCRs).

5. Summary of Changes

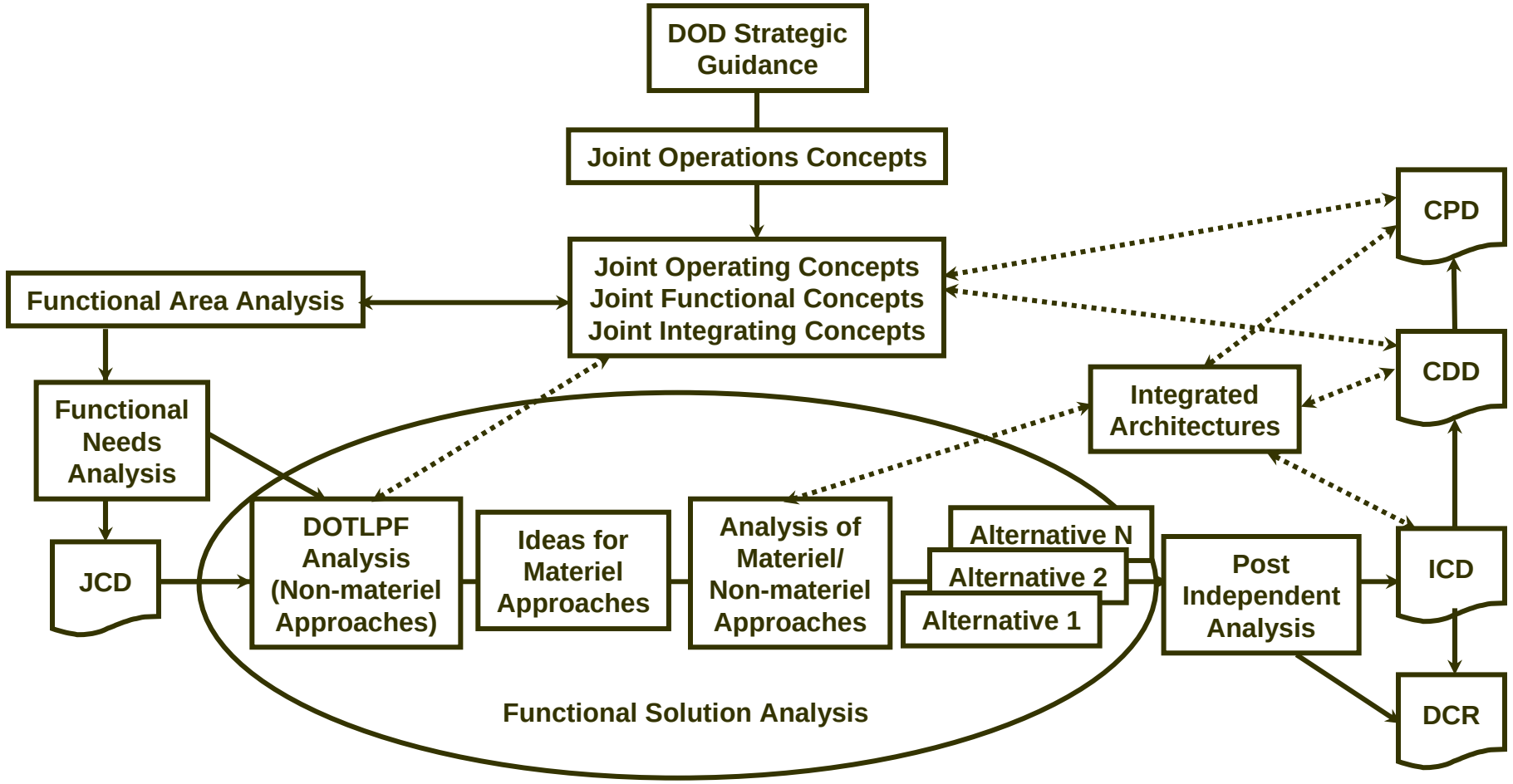
a. Additional guidance on the process of identifying and developing key performance parameters (KPPs) has been given. This includes new guidance on linking KPPs to the key characteristics in the Joint Operations Concepts (JOpsC).

- **Capabilities-based assessment (CBA) composed of a structured**
- **Four-step methodology that defines capability gaps**
- **Capability needs and approaches to provide those capabilities within a specified functional or operational area.**

JCIDS Is an Engineering Intensive Function

- JCIDS activities are fundamental Systems Engineering actions
  - Consistent with the Systems Engineering Method
  - Performed at early concept analysis and development
  - But also at each capability upgrade
- JCIDS analysis quantifies material and non-material options
  - Systems Engineering life-cycle phases quantifies the phases of “Materialization”
    - Abstract concepts in early phases
    - Concrete systems and subsystems as the life cycle progresses

JCIDS Process



**CJCSM 3170.01B*

JCIDS Events

- Functional Area Analysis (FAA)
  - Identify operational task, conditions, and standards needed to accomplish military objectives
  - **Result:** Tasks to be accomplished
- Functional Needs Analysis (FNA)
  - Assess ability of current and programmed capabilities to accomplish the tasks
  - **Result:** List of capability gaps
- Functional Solutions Analysis (FSA)
  - Operational based assessment of DOTMLPF approaches to solving capability gaps
  - **Result:** Potential DOTMLPF approaches to capability gaps
- Post Independent Analysis
  - Independent analysis of approaches to determine best fit
  - **Result:** Initial Capabilities Document

JCIDS

- JCIDS analytical process stresses the fundamentals for applying an effective systems engineering program by any accepted standard
- It guides the “front-end” phases of the SE process for each capability iteration
  - Enterprise (operational) analysis
  - Requirements definition
  - Life-cycle phase
- The analysts must have a thorough understanding of existing capabilities as well as the capability needs
- The JCIDS analysis team eventually determines the optimum combination of material and non-material alternatives to achieve the capability needs to the Battle Force

Perspective

- Not an authoritative review of DoD policy and procedures
  - Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01, “Joint Capabilities Integration And Development System”
  - Chairman of the Joint Chiefs of Staff Manual (CJCSM) 3170.01, “Operation of the Joint Capabilities Integration and Development System”
- Relationship to the acquisition process
- Discuss some thoughts on implementation
  - FAA, FNA, FSA, and PIA
  - No definitive cookbook for implementation

The JCIDS Meta-Model

- OMG SysML™ model of JCIDS activities and artifacts
  - Activities
    - FAA
    - FNA
    - FSA
    - PIA
  - Artifacts
    - Architecture model
      - Including capability use cases
    - ICD, CDD, CPD
    - DOTMLPF Change Recommendations
    - Integrated Threat Warning Assessment (ITWA)
    - CONOPS

OMG SysML™

- Diagrams used throughout this presentation are constructed using the Object Management Group's SysML (Systems Modeling Language)
- Systems engineering extension to Unified Modeling Language (UML™) 2.0
- OMG SysML is a standardized family of diagrams depicting system elements, their behaviors and their relationships with other elements internal and external to the system
  - Captures operational and systems requirements
  - Documents element parametrics and constraints
  - Methodology independent

For a detailed discussion on SysML, each of you are invited to attend Abe Meilich's SysML Tutorial this afternoon

Targeting and Bomb Damage Assessment

- Read the attached "Statement of Operational Need" at the break
- TBDA represents a required capability to:
  - Maintain persistent coverage over a target area
  - Acquire fire-control quality track files on moving targets
  - Provide the means to determine whether a target was sufficiently destroyed or neutralized
  - Must be able to be deployed by a small team of ground-based personnel
  - Controlled by the local ground commander

TBDA is a FICTICIOUS Case! Any similarity with any capability or system, real or imagined, is purely coincidental!

TBDA Presentation

- This case presents a very limited sample of artifacts and elements that are part of the FAA, FNA and FSA SE Model
- Intent is to illustrate modeling possibilities using SysML
  - Requirements traceability
  - Entities with their behaviors and relationships
    - Material and non-material
  - Standards that govern architectural elements

Systems Engineering Method

David Flanigan

October 23, 2006

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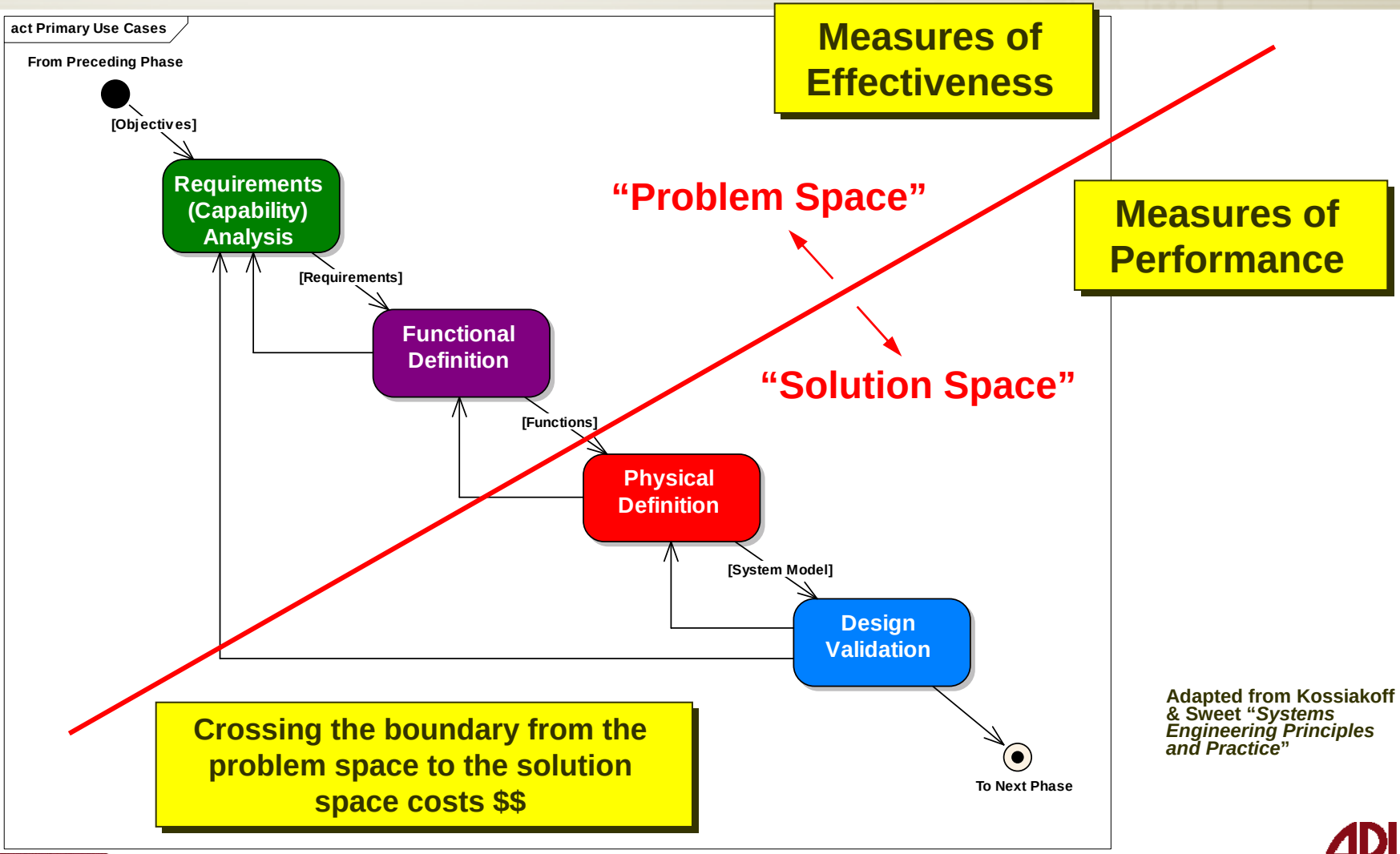
Discussion Topics

- Describe Systems Engineering Method (SEM) in JCIDS context
  - Identify and describe four “root” steps
  - Identify inputs/conditions for each step
  - Identify outputs/products from each step
  - Inter-relationships among the steps
- Show linkage to JCIDS and the Systems Engineering lifecycle

Systems Engineering Method

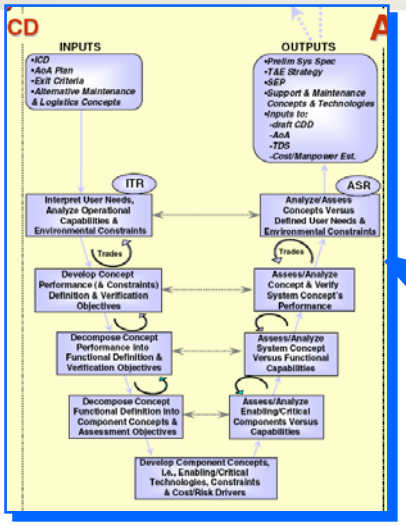
- Regardless of the analytical phase performed by the JCIDS SE team,
  - The basic application of the SE method is constant throughout the process
- Each SE Method activity is performed in some form or to some degree in each phase of the system life-cycle

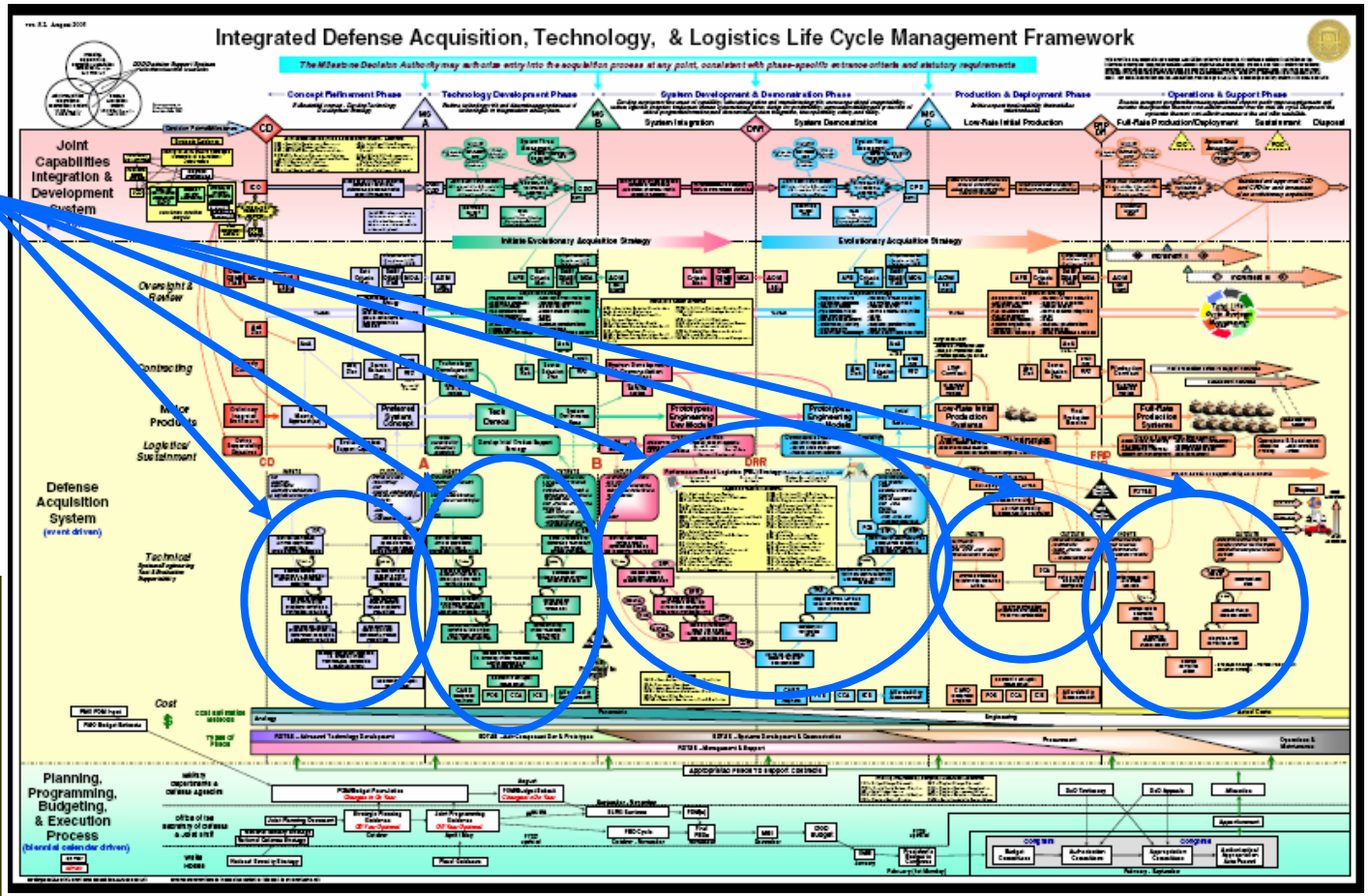
Systems Engineering Method



Adapted from Kossiakoff & Sweet "*Systems Engineering Principles and Practice*"

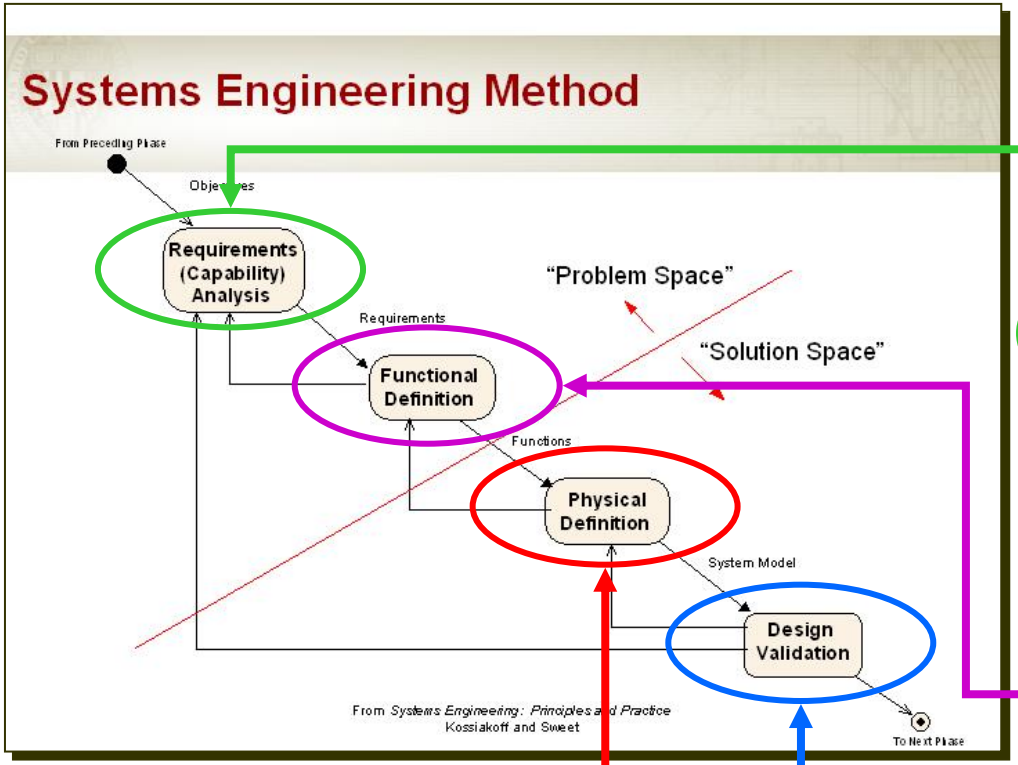
Systems Engineering Method Over Life Cycle

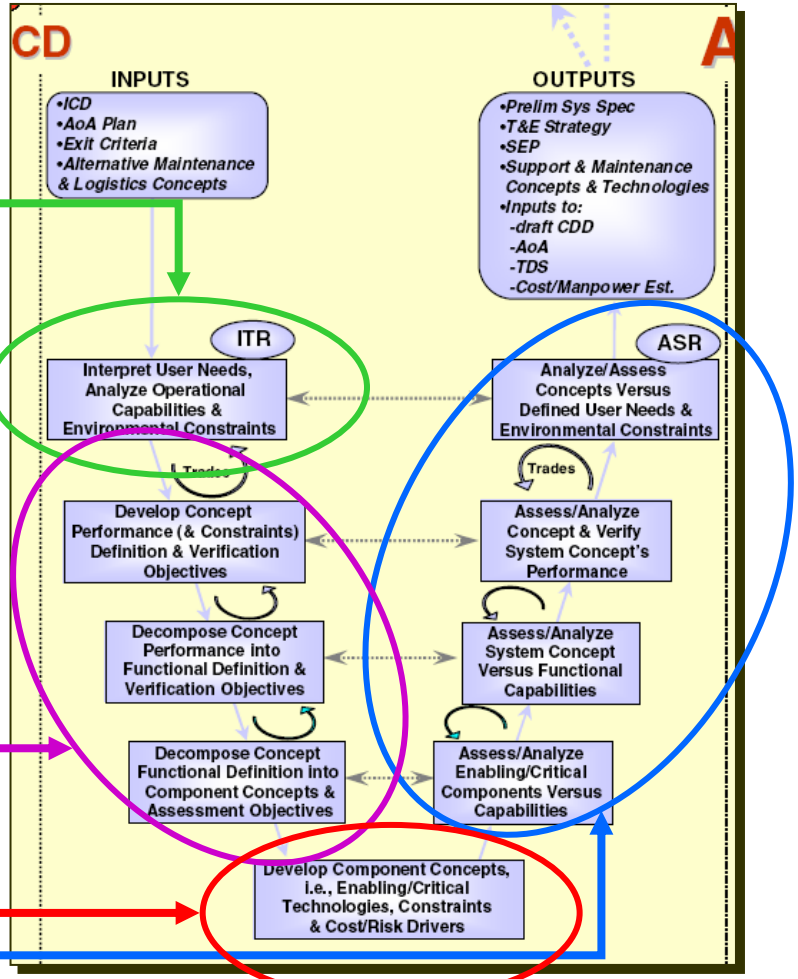




The Systems Engineering "V" is iterative and tailored throughout the entire lifecycle

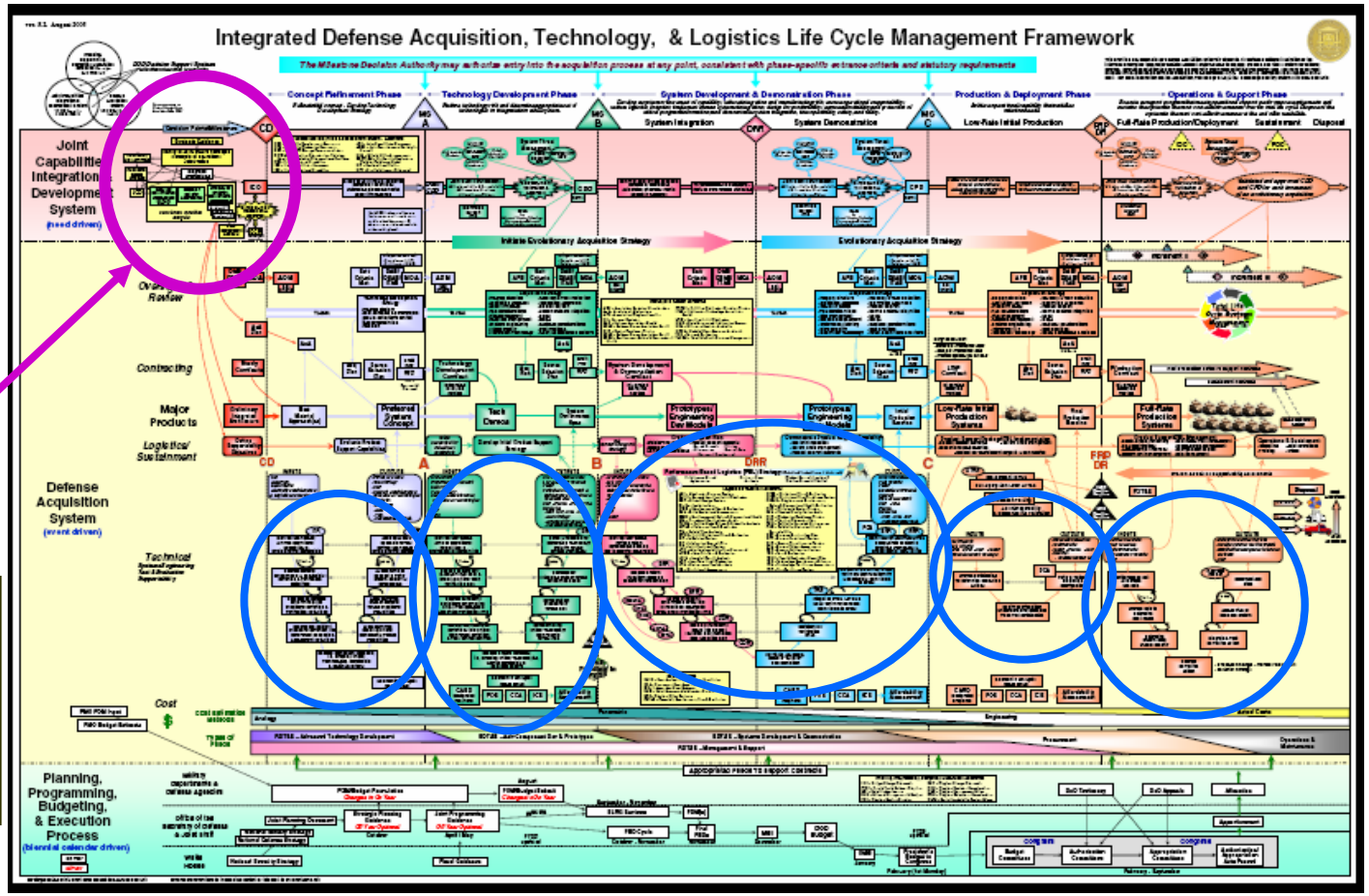
Systems Engineering Method Over Life Cycle





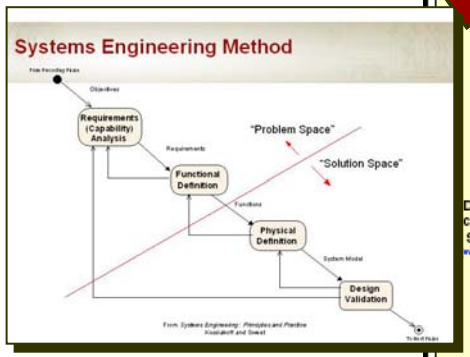
The generic SE method can be mapped to each specific iteration of the SE "V"

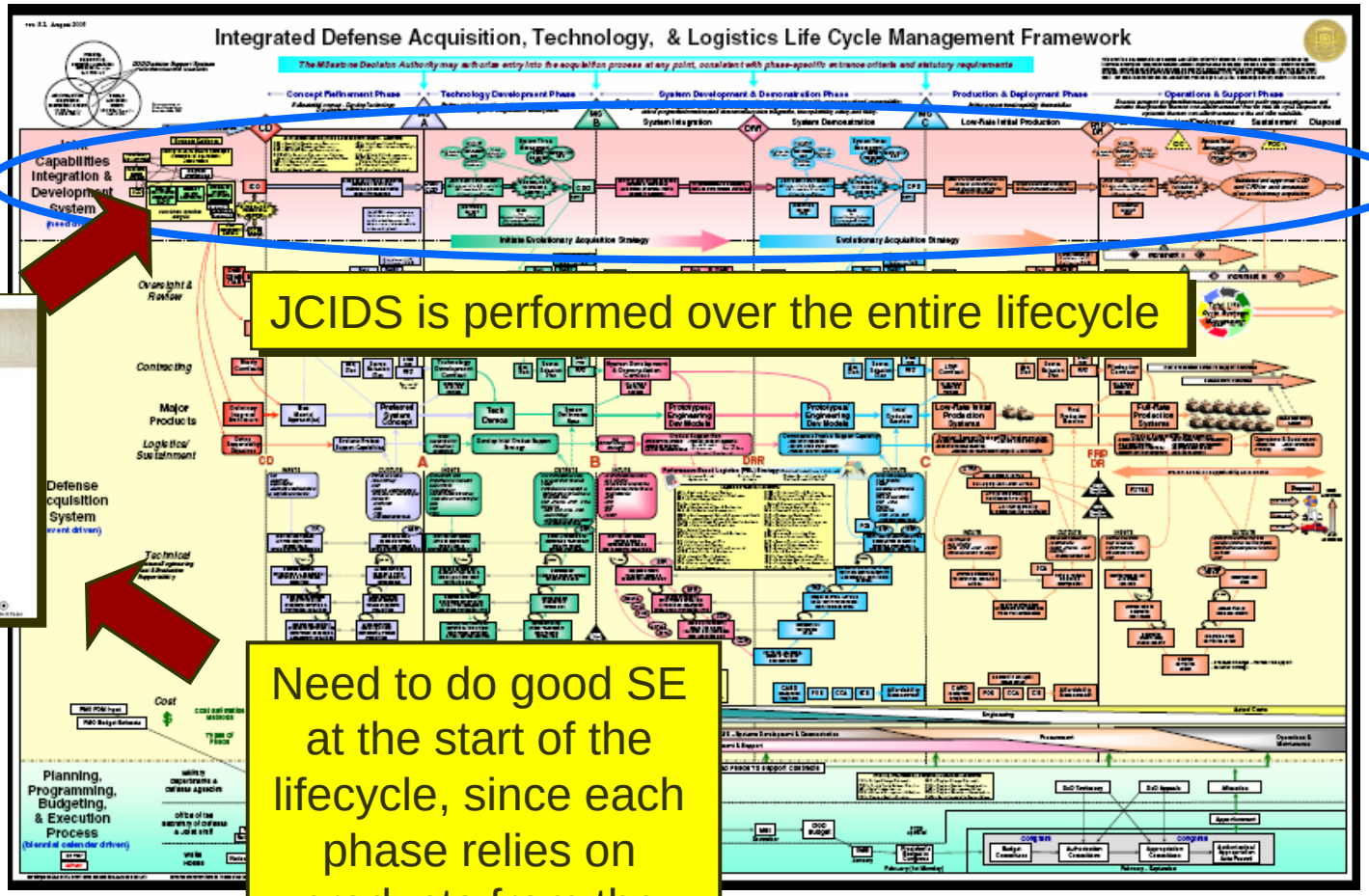
Systems Engineering Method Over Life Cycle



The front end of JCIDS has no Systems Engineering "V"

Systems Engineering Method Over Life Cycle

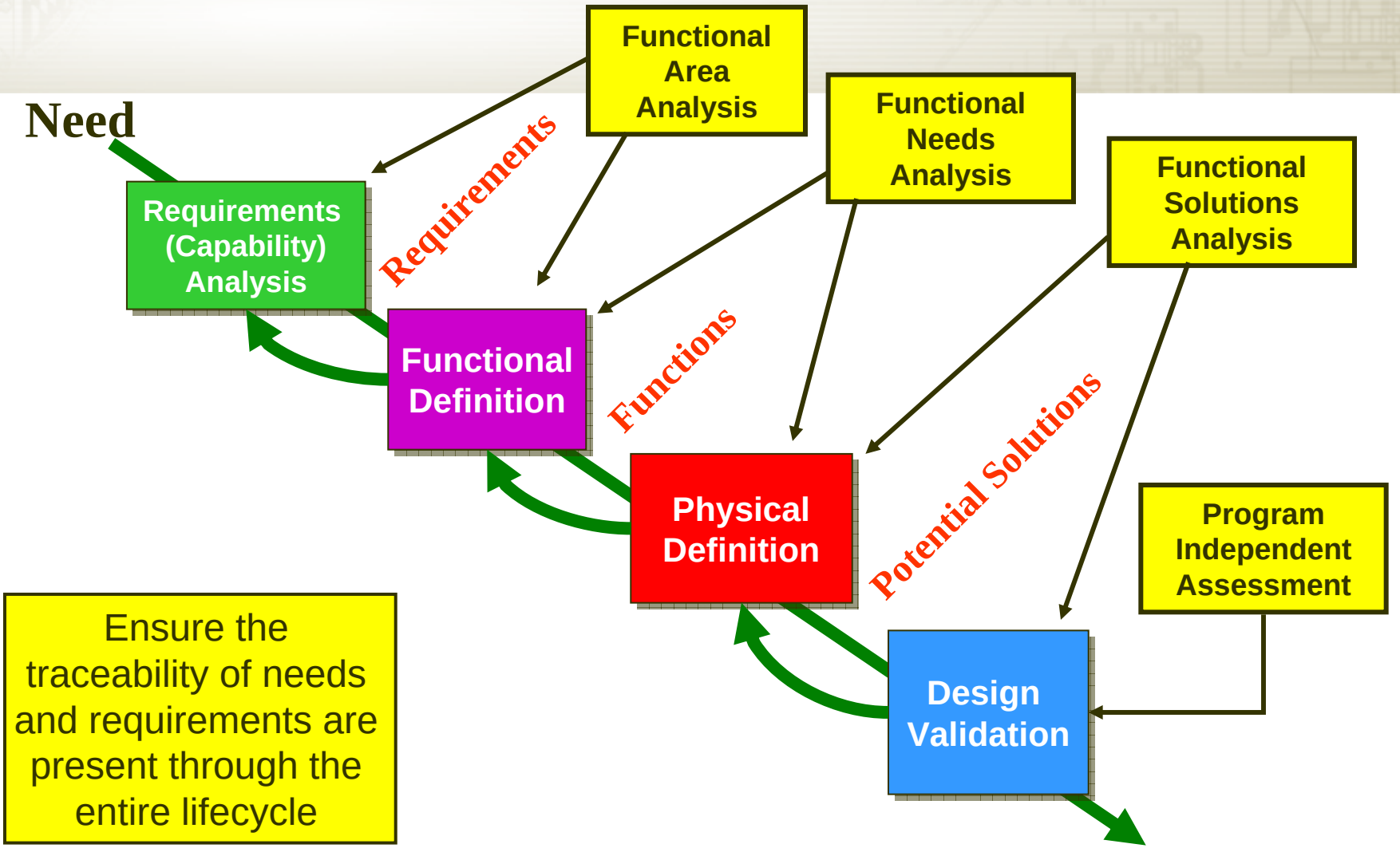




JCIDS is performed over the entire lifecycle

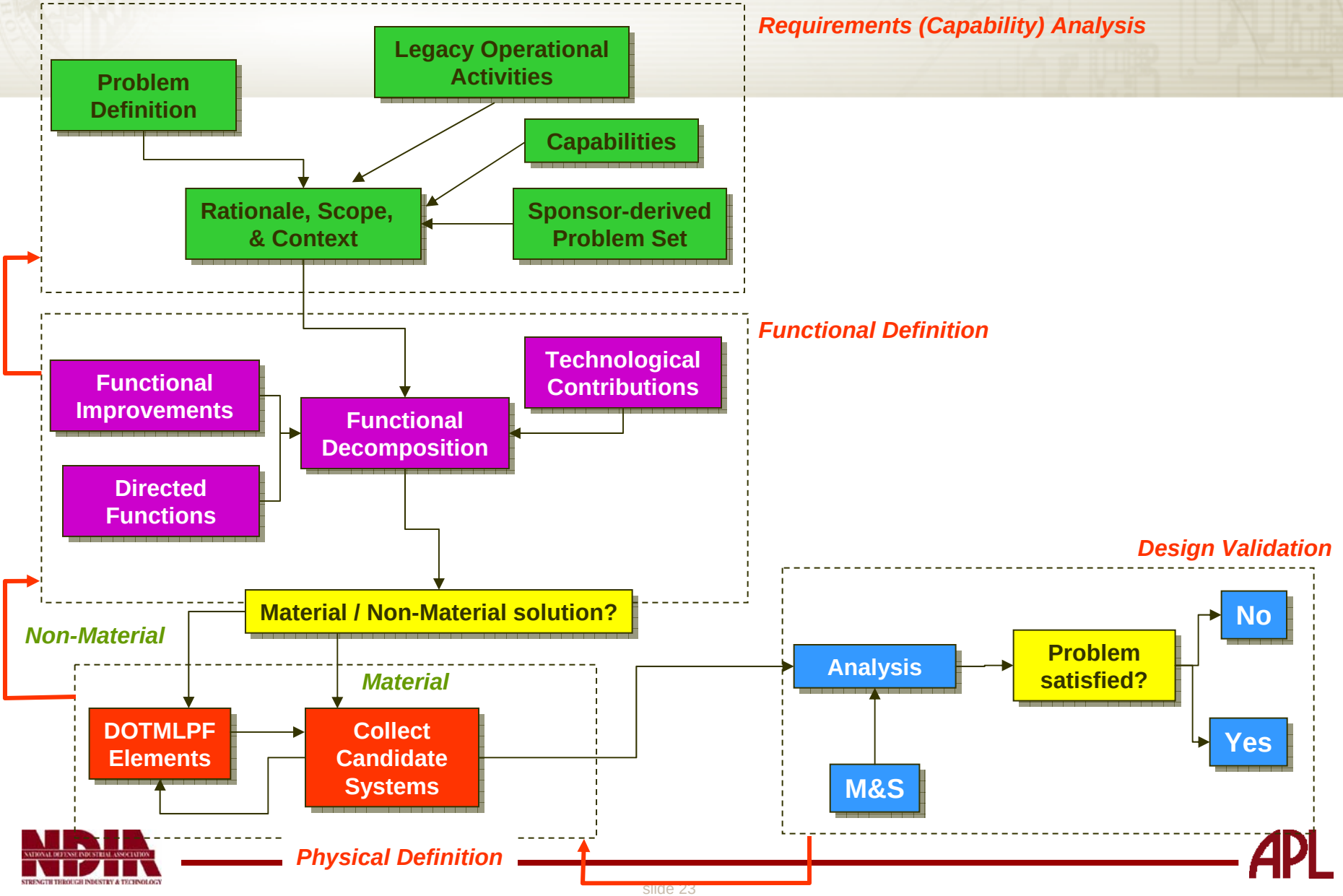
Need to do good SE at the start of the lifecycle, since each phase relies on products from the previous phase

Systems Engineering Method



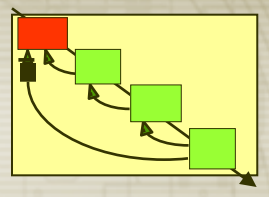
Ensure the traceability of needs and requirements are present through the entire lifecycle

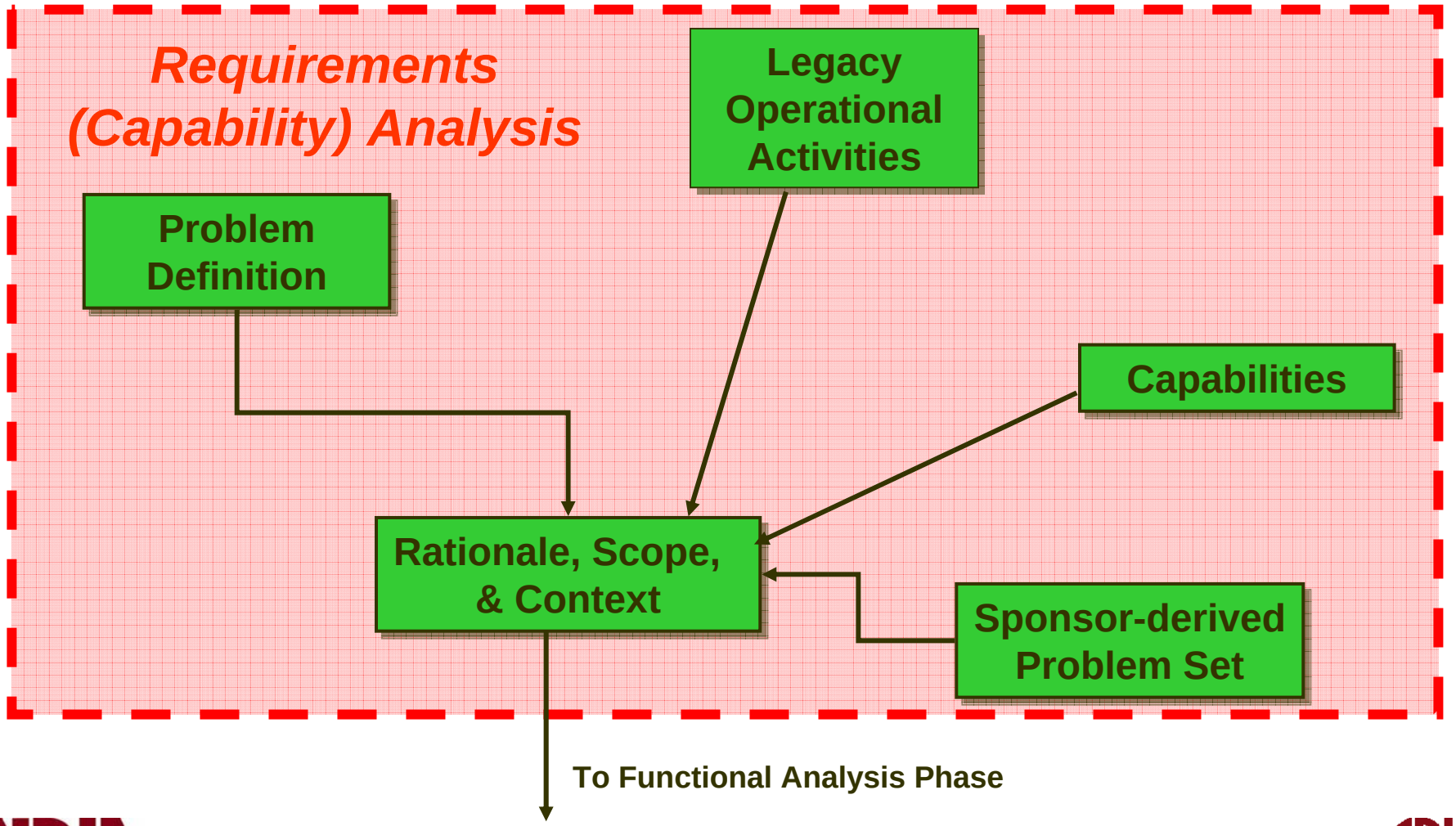
Systems Engineering Method



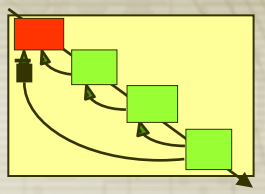
Systems Engineering Method

Phase 1: Requirements (Capability) Analysis





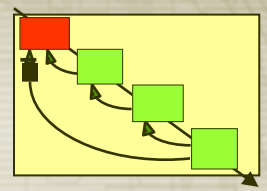
Problem Definition



- At one point in time there is a problem that must be solved due to:
  - Deficient capability with existing systems
  - Desire to improve existing performance
- Need to understand what the objectives are to provide the desired capability
- Define the operational context within the Capability Enterprise!

Did we define the problem correctly?
Did we define the correct problem???

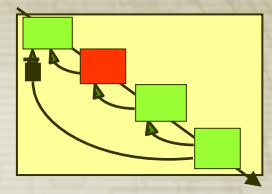
Example Requirements Analysis Products



- Clear(er) definition of the problem
- Proper scope of the problem
- Operational context documents and data bases
  - Design Reference Mission
  - Strategy-to-Task Mapping
  - Concept of Operations
  - Physical Environment Database
  - Threat Representation Database
  - Blue Capabilities Database
- Relevant Operational Views

Captured within a SE Requirements Model

Systems Engineering Method
Phase 2: Functional Definition



From Requirements Definition

Functional Improvements

Technological Contributions

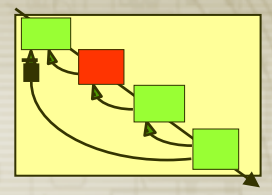
Functional Decomposition

Directed Functions

Functional Definition

To Physical Definition

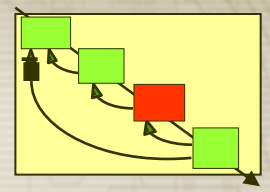
Typical Functional Definition Products

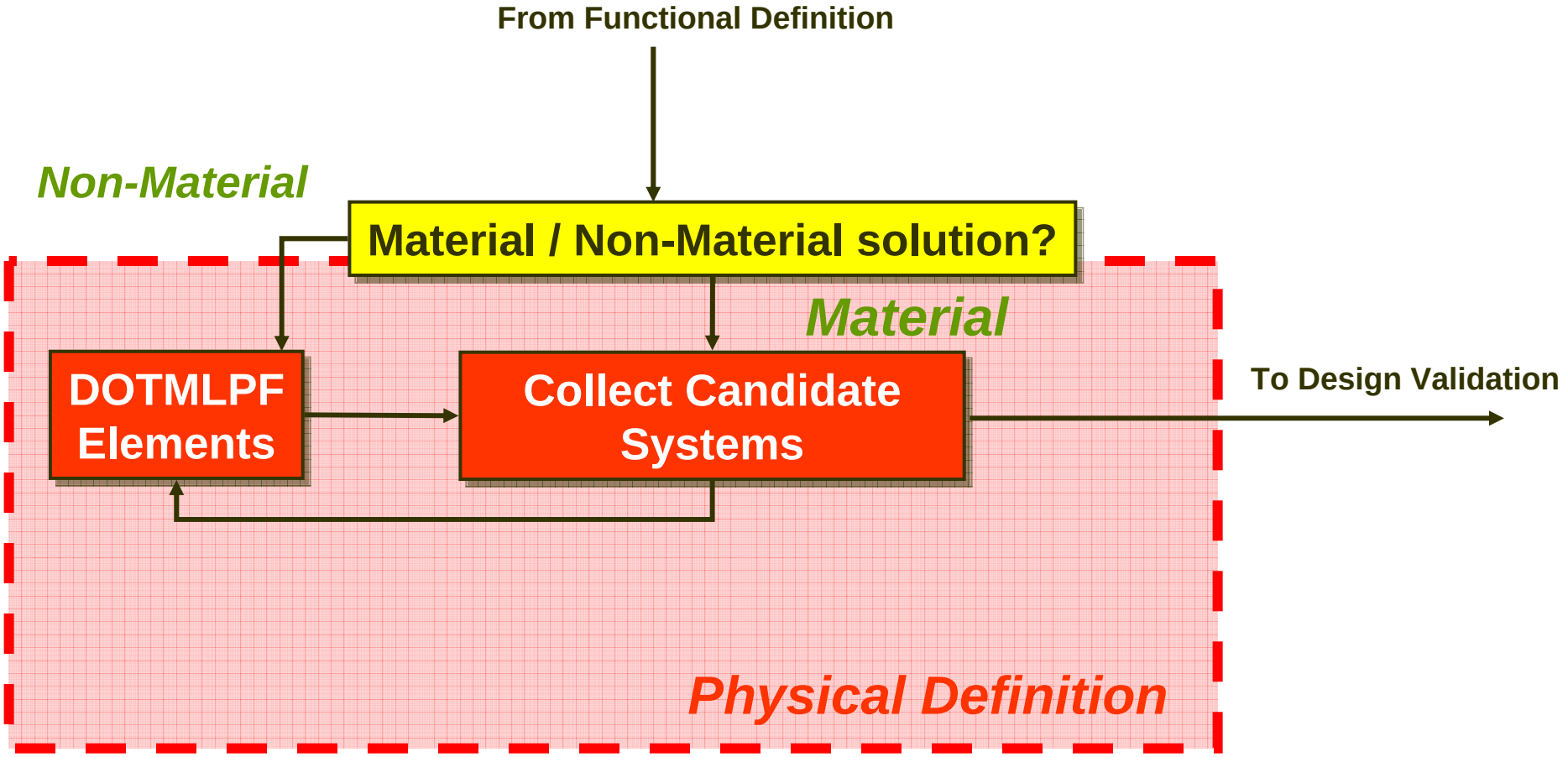


- Functional Decomposition of required activities
  - Functional diagrams (Functional Flow Block Diagrams, UML Activity Diagrams)
- Associated metrics with these functions (threshold / objective)
- Analysis process that determines if you can solve with a material / non-material / both solution
  - Be able to document and defend this process
- How do we know it's right?
  - The functions are legitimate, correct, and validated by users
- Functional Area Analysis
- Relevant operational views

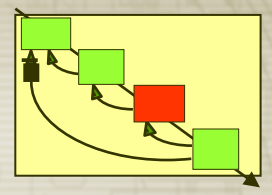
Functional Analysis Documented in a SE Functional or Physical Model

Systems Engineering Method
Phase 3: Physical Definition





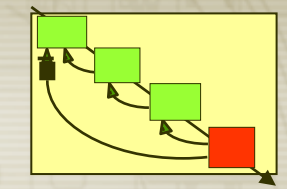
Typical Physical Definition Products



- Provide system alternatives towards satisfying required functionality
  - Assignment of functions to physical elements
- DOTMLPF analysis products
  - Based on the functional definition phase
- CONOPS changes / recommendations
  - Based on DOTMLPF analysis
- Risk management strategies of the system
- System roadmaps to bridge the gap between the current and future capabilities
- Functional Needs Analysis
- Relevant operational and SYSTEMS views

SE Physical Model with Physical Definition Begins Evolution Toward a Systems Model

Systems Engineering Method
Phase 4: Design Validation



From Physical Definition

Analysis

M&S

Problem satisfied?

No

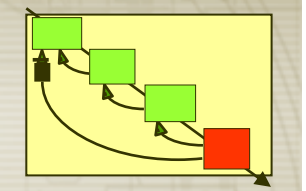
Reassess requirements, functional elements or physical details

Yes

To next life-cycle phase: Requirements Definition

Design Validation

Typical Design Validation Products



- Demonstrate the analysis documents the assumptions, follows a rigorous process, and arrives at meaningful conclusions that are justifiable
  - There may be multiple processes and products dependent on the sponsor, personnel/time availability, experience
  - This may be an iterative process for ICD, CDD, CPD
- Trade studies
- VV&A
- Risk Management
- Cost Analysis
- Force Allocation
- Functional Solutions Analysis
- Program Independent Assessment

Attain a Fully Validated Systems Engineering Model

Systems Engineering Methodology
Linkage to JCIDS Summary

- SE methods can be used to produce JCIDS products/artifacts
- SE methods can iterate throughout the DoD 5000 lifecycle
- Good SE methods can produce JCIDS
- Bad SE methods can produce JCIDS
- Producing JCIDS does not guarantee good SE

Good SE ⟷ Effective JCIDS

Applying Model-Driven Systems Engineering Practices to JCIDS

Jennifer Rainey

October 23, 2006

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Discussion Topics

- **Purpose –a model-driven systems engineering (MDSE) approach supports the JCIDS lifecycle process**
- **What is Model-Driven Systems Engineering?**
- **How to Apply Model-driven Systems Engineering for JCIDS?**

Purpose

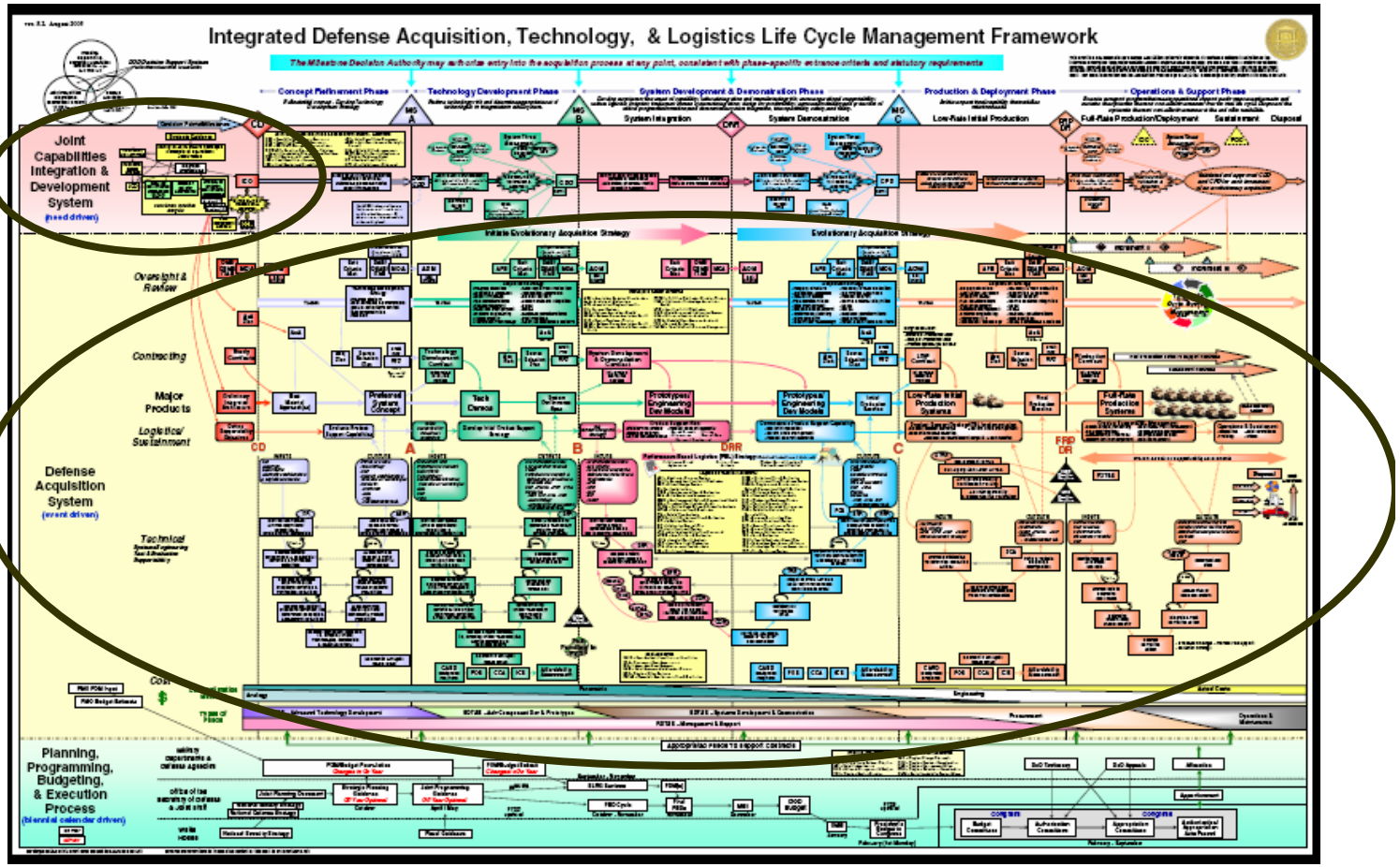
- A Model Driven Systems Engineering (MDSE) approach supports the entire defense acquisition, technology, and logistics lifecycle
  - A systems engineering model provides traceability from system development back to initial JCIDS process and war fighting need
  - MDSE focuses on techniques that drive capability identification
    - Documents entire system lifecycle
    - Identifies the capabilities, capability gaps, and materiel/non-materiel solutions
    - Develops foundation for integrated architectures
  - JCIDS is a concept-centric capabilities identification process
    - "The process to identify capability gaps & potential material and non-materiel solutions must be supported by a robust analytical process that incorporates innovative practices…"
      - CJCSI 3170.01E 11 May 2005

Use of model-driven SE facilitates JCIDS throughout the systems lifecycle

Integrated Defense Acquisition, Technology, & Logistics Lifecycle Management Framework

MDSE should be used here

MDSE is used here



Systems Engineering Model

- A model is a representation of a system
  - Assists stakeholders, including engineers, to understand something that is not easily comprehensible
  - Communicates the organization of the system to stakeholders
  - Enhances understanding of interfaces, relationships, operations and risk
  - Continually updated

- Systems Engineering Model
  - Build as the basis for JCIDS analysis
  - Covers the problem and solution space
  - Contains the objects, relationships and the data
    - Requirements, Functional, and Physical
  - Develops the integrated architecture

Systems Engineering Model is a Living Entity

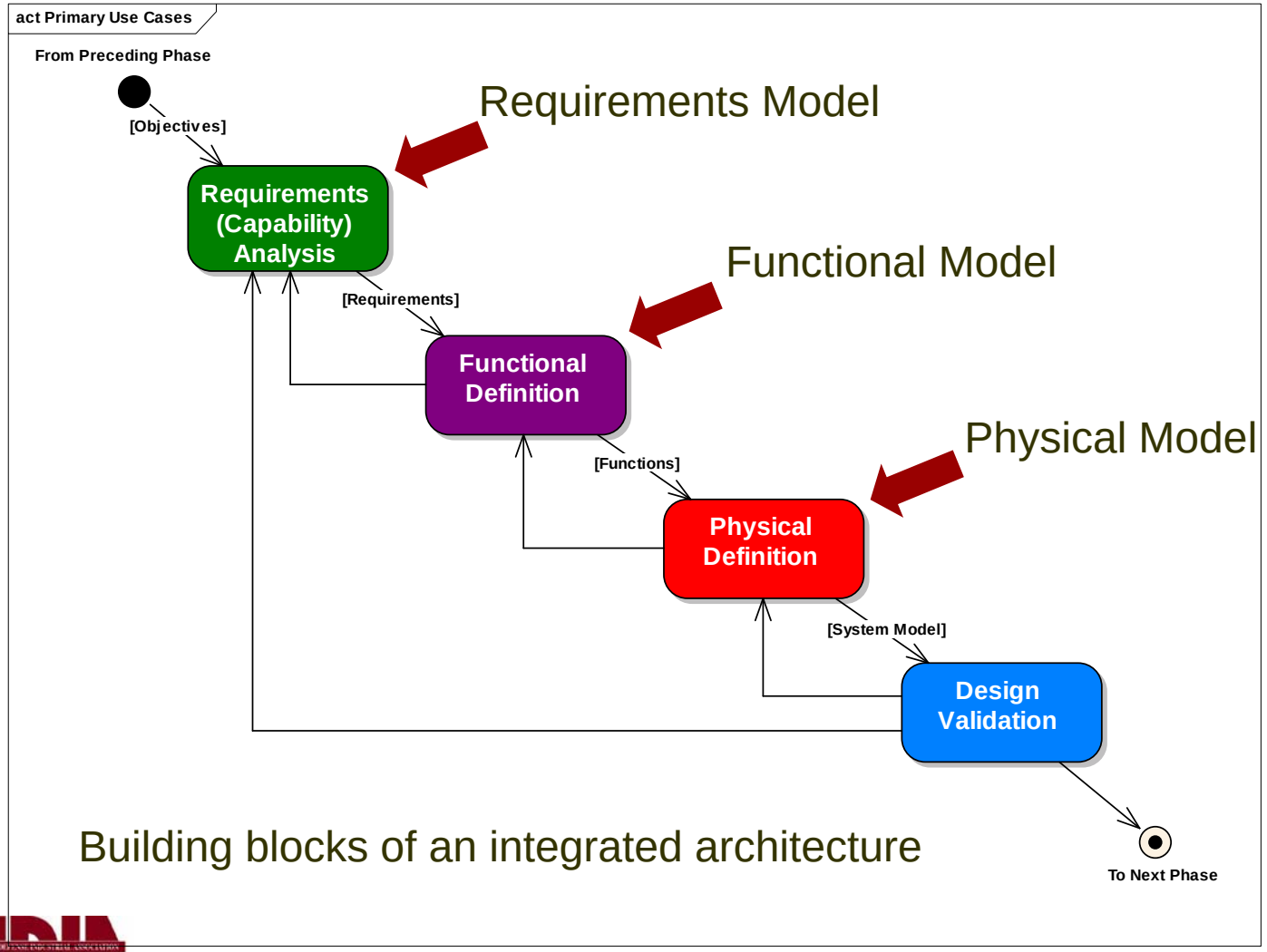
Model-Driven Systems Engineering

- **Establish system model bases on:**
  - **Requirements model**
  - **Functional model**
  - **Physical model**

- **Show relationships between the models**
  - **Link operational needs to capabilities**
  - **Link capabilities to requirements**
  - **Link requirements to functions**
  - **Link functions to systems**

"If you don't model it, you won't understand it."
Ivar Jacobson

Systems Engineering Method



Adapted from Kossiakoff & Sweet "*Systems Engineering Principles and Practice*"

Requirements Model

- Requirements Analysis
  - Define/scope the problem space
  - Identify “capabilities” during JCIDS process to meet war fighting needs
    - Capabilities turn into requirements later in the lifecycle
  - Analyze capabilities/requirements
    - Assess against “as-is” capabilities/systems, identify gaps
    - Ensure they are necessary, concise, attainable, complete, consistent, unambiguous, and verifiable
    - Create requirements traceability
  - Products:
    - Framework for Operational Views
      - Fulfill need to develop DoDAF operational view artifacts
      - Sets standards to be used needed for technical view artifacts
    - Metrics
      - Measures of Effectiveness
      - Measures of Performance
    - Operational context documents

Functional Model

- **Functional Definition**
  - **Implementation free identification of required activities**
  - **Establish functional decomposition**
    - **Use Cases, Operational Scenarios**
    - **Functional Flow Block Diagrams (FFBDs)**
    - **Unified Modeling Language (UML) Activity Diagrams**
  - **Can model the time sequencing of the functions**
  - **Show data or information flow between functions**
    - **Fulfill need to develop DoDAF operational view artifacts**
    - **Fulfill need to develop DoDAF system view artifacts**
  - **Products:**
    - **Capabilities/functionality needed to meet requirements**
    - **Refined performance metrics**
    - **Framework for Operational and System Views**

Physical Model

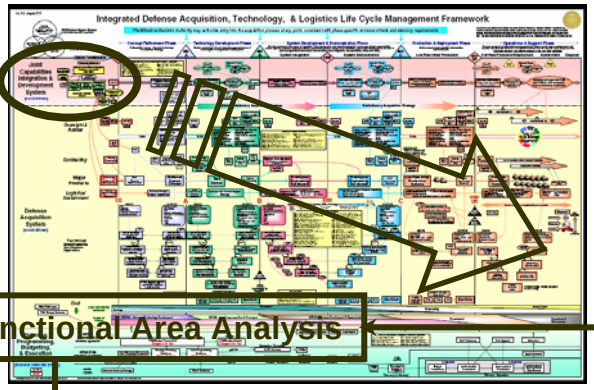
- Physical Definition – solution space
  - Set the system context or boundary
    - Context diagrams
    - Class diagrams
- Allocate functions to physical elements
    - Evaluate “to-be” capabilities against “as-is” capabilities and systems to identify the “capability gaps” and “redundancies”
    - Establish link to requirements
- Products:
    - System Elements
    - Relevant system views
    - System data exchanges
    - System roadmaps to bridge the capability gap

Formed the Systems Engineering Model

The Systems Engineering Model

- Where it all ties together!
  - Formed by establishing the relationships between the requirements, functional, and physical elements of the model
    - Requirements (capabilities) link to functions, functions are allocated to physical components
      - Early in the process, the system solution can be expressed as a “black box”
      - As the lifecycle advances, the physical model is further refined into sub-systems
        - Ensure every requirement is linked to a function
        - Ensure every function is allocated to physical element
    - The MDSE process forms the basis for the integrated architecture
  - Supports impact analysis
    - The SE Model developed during upfront JCIDS is the same model used during the entire acquisition lifecycle
    - Traceability is maintained back to the original capability need identified
      - Allows greater understanding of the impact of how changing one element in the model, impacts other areas

MDSE Basis for Integrated Architectures



DOD Strategic Guidance

Joint Operations Concepts

Joint Operating Concepts
Joint Functional Concepts
Joint Integrating Concepts

Functional Area Analysis

Functional Needs Analysis

Integrated Architectures

CPD

CDD

ICD

DCR

JCD

DOTLPF Analysis (Non-materiel Approaches)

Ideas for Materiel Approaches

Analysis of Materiel/ Non-materiel Approaches

Alternative N

Alternative 2

Alternative 1

Post Independent Analysis

Functional Solution Analysis

Architectures in JCIDS

- **"Integrated Architectures" are a foundation for the analytical process**
  - **Stated requirements, attributes, and measures**
  - **Meets DoDAF needs**
  - **Used during upfront JCIDS, concept refinement, technology development, system integration, system development, and production**
  - **System model defines the architecture used during the lifecycle**

- ***"Key components of the CDD and CPD are the integrated architecture products that ensure the DoD understands the linkages between capabilities and systems and can make appropriate acquisition decisions."* CJCSI 3170.01E 11 May 2005**

The "Systems Model" becomes the basis for architecture and JCIDS analysis

Architecture Views

- Architecture Views
  - A view is a different “slice” of the model
  - Provides a look “inside” the model
  - Includes information relevant to the stakeholder

- An architecture engenders a multitude of artifacts
  - Most are derived using the same information and data elements
    - Can be obtained from the systems engineering model
  - DoDAF architecture views are specific types of artifacts
    - Includes Operational, Systems, and Technical Views
  - DoDAF architecture views are just a few of the possible model views

JCIDS Systems Engineering Model

- A Systems Engineering model captures the essential elements of the systems engineering life-cycle
- "Dynamic and recursive process" (Bootch, Rumbaugh, Jacobson)
  - Iteratively captures enterprise capabilities and system requirements
  - Promotes incorporation of technology evolution
- Forms basis for sound, long-term systems engineering and analysis
  - Compliant with DoDAF and JCIDS

Model-Driven SE in Defense Systems Acquisition becomes Model-Driven JCIDS

How to Apply MDSE to JCIDS

- Establish a meta-model to understand the framework for the process
- Meta-model is another abstraction, highlighting the properties of a model
  - *Explicit* description (constructs and rules) of how a domain-specific model is built
- JCIDS meta-model is composed of:
  - Dynamic elements – modeling the behavior over time
  - Logical elements – static view of the objects and classes

Need to model JCIDS process as a "meta-model"

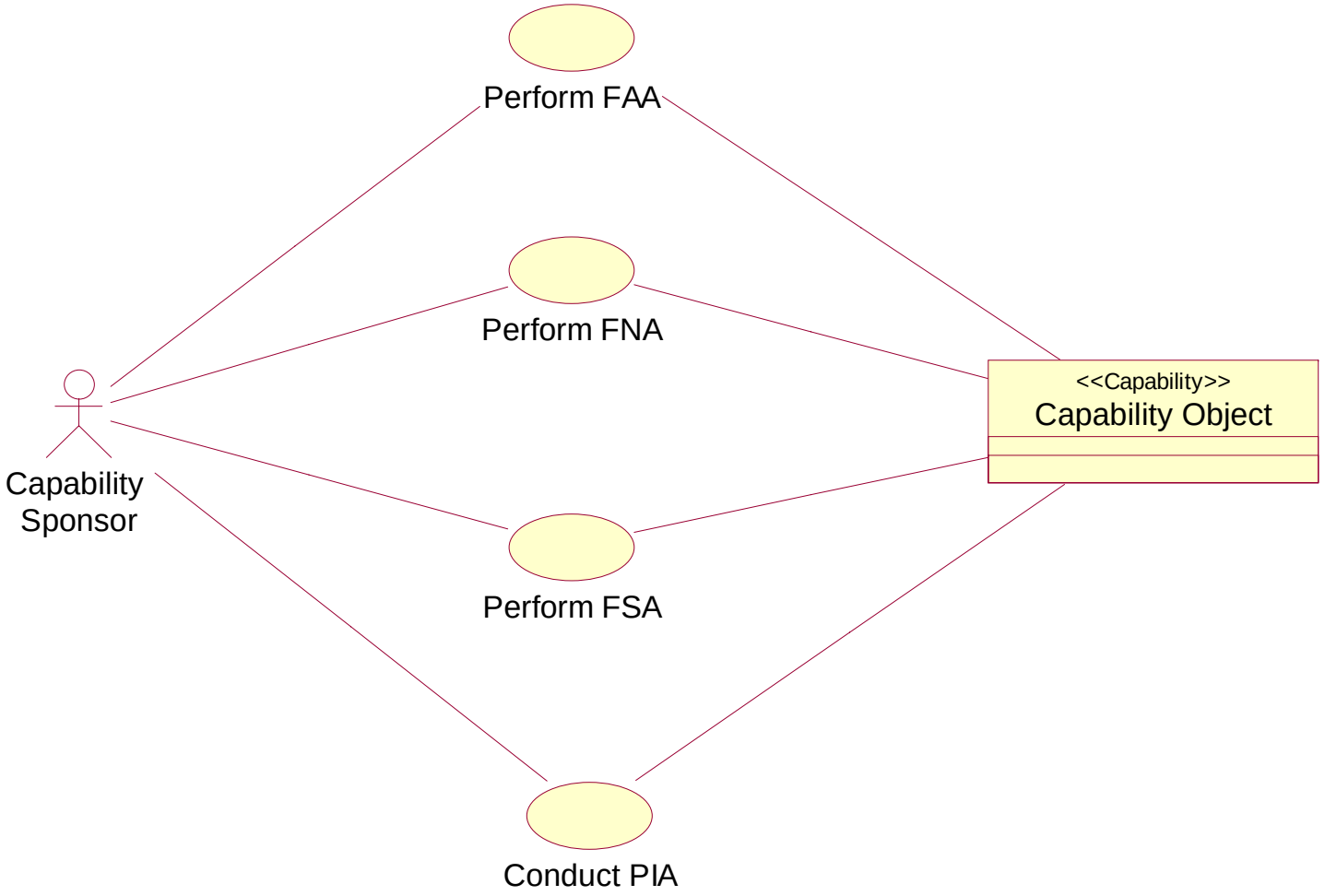
The JCIDS Meta-Model

- Dynamic Component
  - Incorporates model-driven analyses within the JCIDS process
  - Standardizes SE modeling methods demonstrate utility for modeling JCIDS capabilities
  - Applies the model-driven approach to each JCIDS analytical phase
    - Leading up to JCIDS analyses documentation
    - Appropriate for capability iterations throughout the Warfare Systems' lives
      - Easily updated and maintained
      - Use throughout the acquisition lifecycle
- Logical Component
  - The Capability Object exists within the "Capability Enterprise"
  - Captures logical and dynamic elements
  - Identifies the attributes and operations of a Capability Object functioning within the operational domain
  - Identifies "Non-Materiel" elements of DOTMLPF

JCIDS Meta-Model Dynamic Component

- FAA, FNA, FSA, and PIA are represented as use cases
  - Each phase represents a dynamic set of activities
  - With post-condition “Result of Value”
- Relates the JCIDS activities to the process of SE/Architecture modeling
  - Understanding the As-Is Enterprise and evolving the To-Be mission scenarios and use cases

JCIDS Dynamic Model



JCIDS Meta-Model Logical

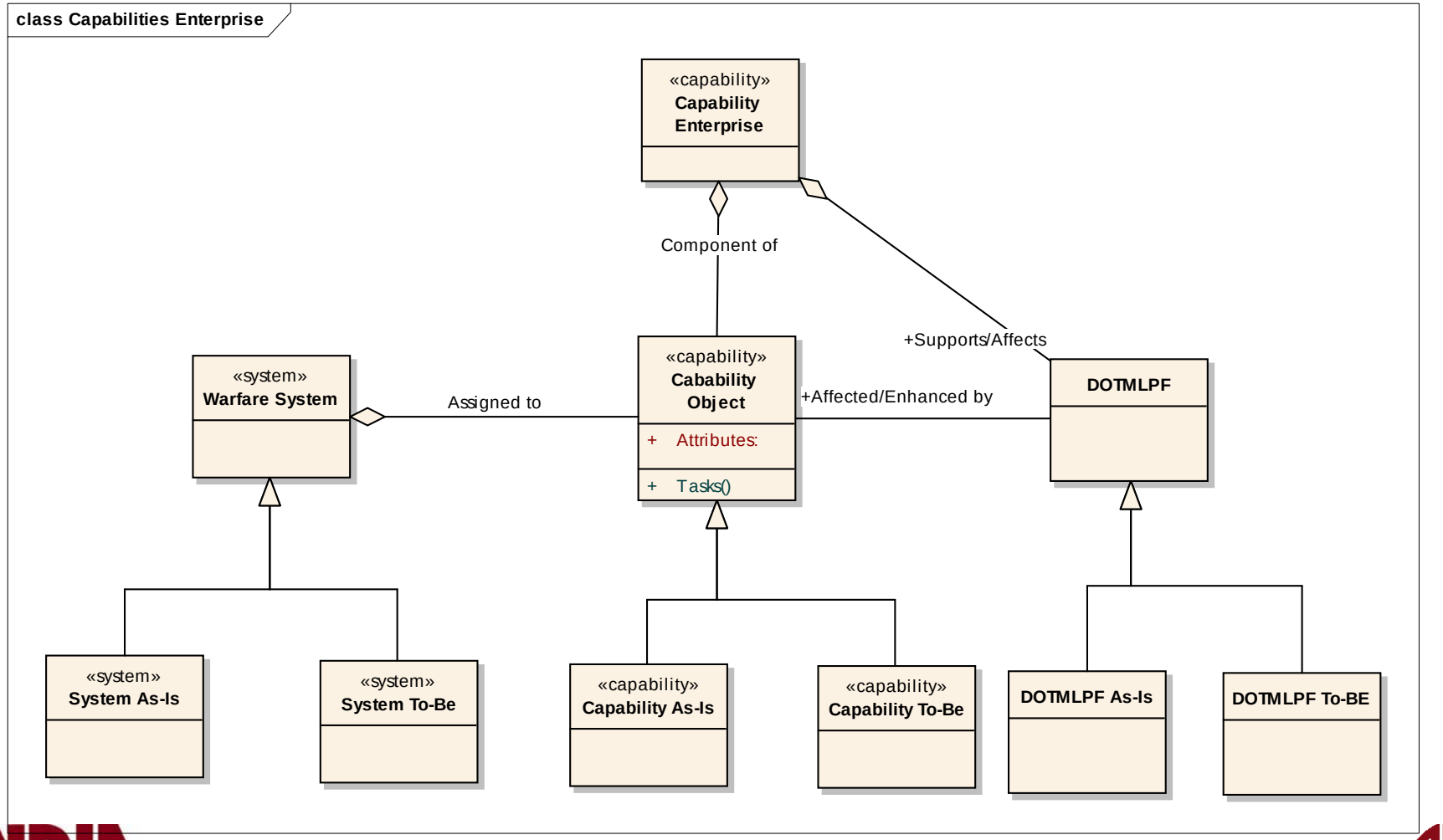
- Focus of analysis is on a Capability Object
  - Enables itself within the Capability Enterprise
- Identification of needed capabilities to fulfill war fighting needs (FAA)
- Baseline Capability Enterprise is composed of As-Is capabilities of legacy As-Is Warfare System
- Comparison of To-Be capabilities against the As-Is baseline yields the Capability Gap(s) (FNA)
- Evolve the capability and allocate to physical To-Be Warfare System (FSA)
- DOTMLPF applies needs analysis and potential solutions

Capability Object

- Form of "System Object" as defined by Object Oriented Systems Engineering Methods (OOSEM)
  - Performs operations on behalf of itself and/or other objects
    - Provide output result of value
    - Provide services and information related elements within the domain
  - Possesses measurable properties
    - Physical, data, performance

- Capability Objects, like all UML classes, possess:
  - Attributes
  - Operations
  - Associations

Capability Object and the Warfare System



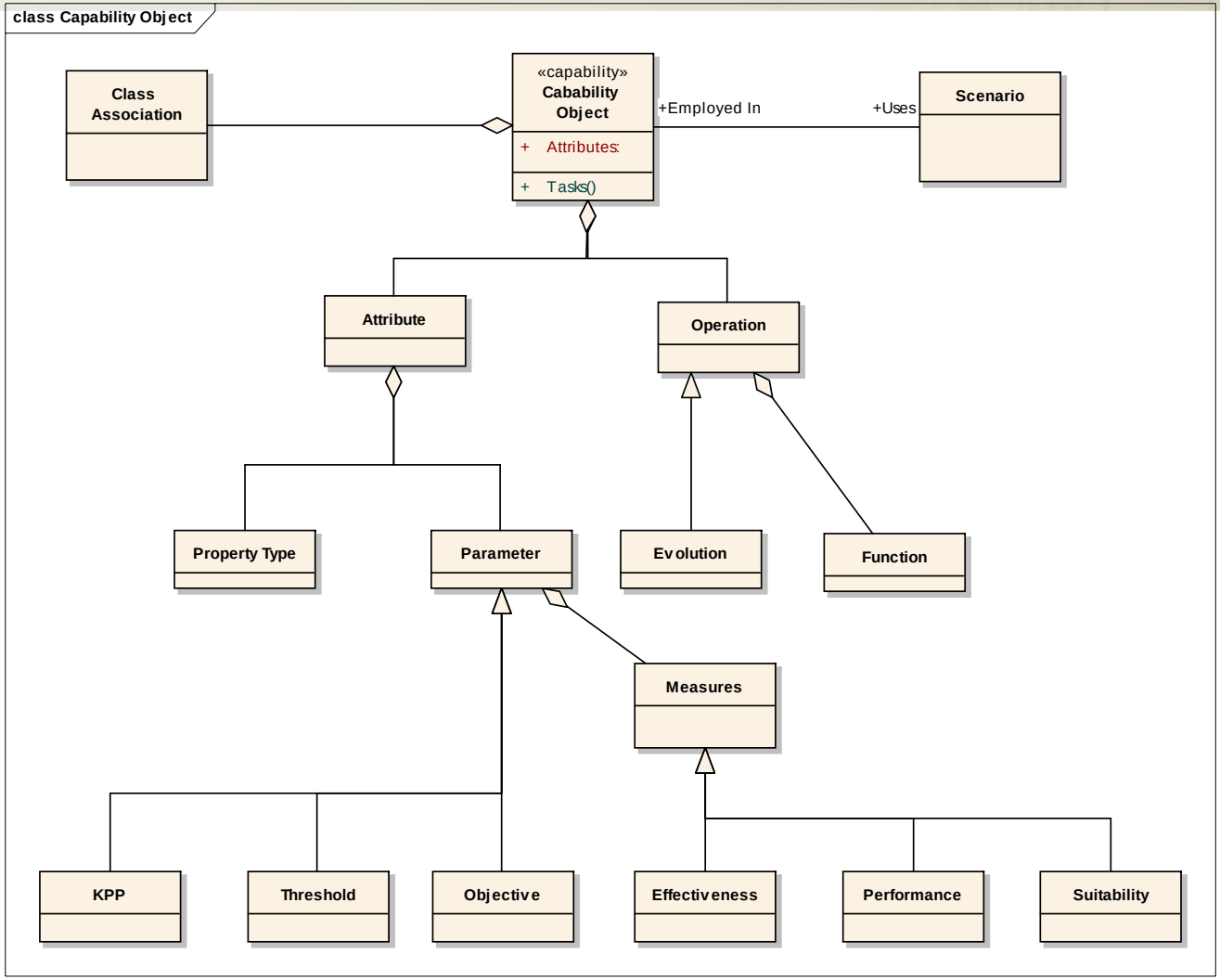
Capability Object

FAA

FNA/FSA

FSA

ICD/CDD/ CPD



Transition from Capability to System

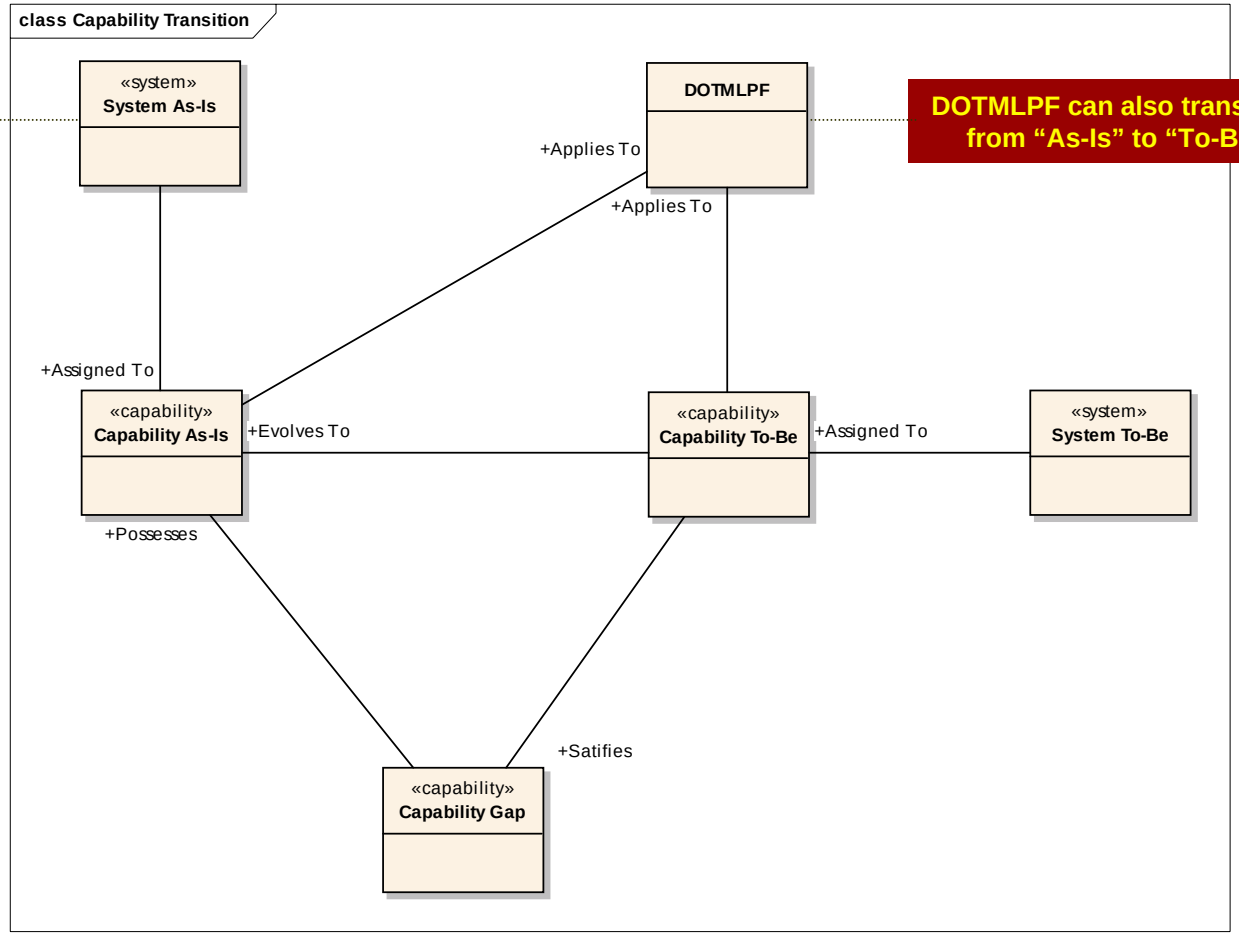
- **Use capability object to perform assessments to satisfy DOTMLPF**
  - **Analysis of Materiel/non-materiel approaches**
  - **Analysis of Alternatives**
  - **Initial Capability Document**

  Investigate if a modification to any element of DOTMLPF except the "M" will enhance the Capability Enterprise
  - **A far less expensive option**

  DOTMLPF elements can be modeled as classes
  - **Each non-materiel element possess attributes and operations**
  - **Helpful to define a meta-class early in the process to understand element components and relationship**

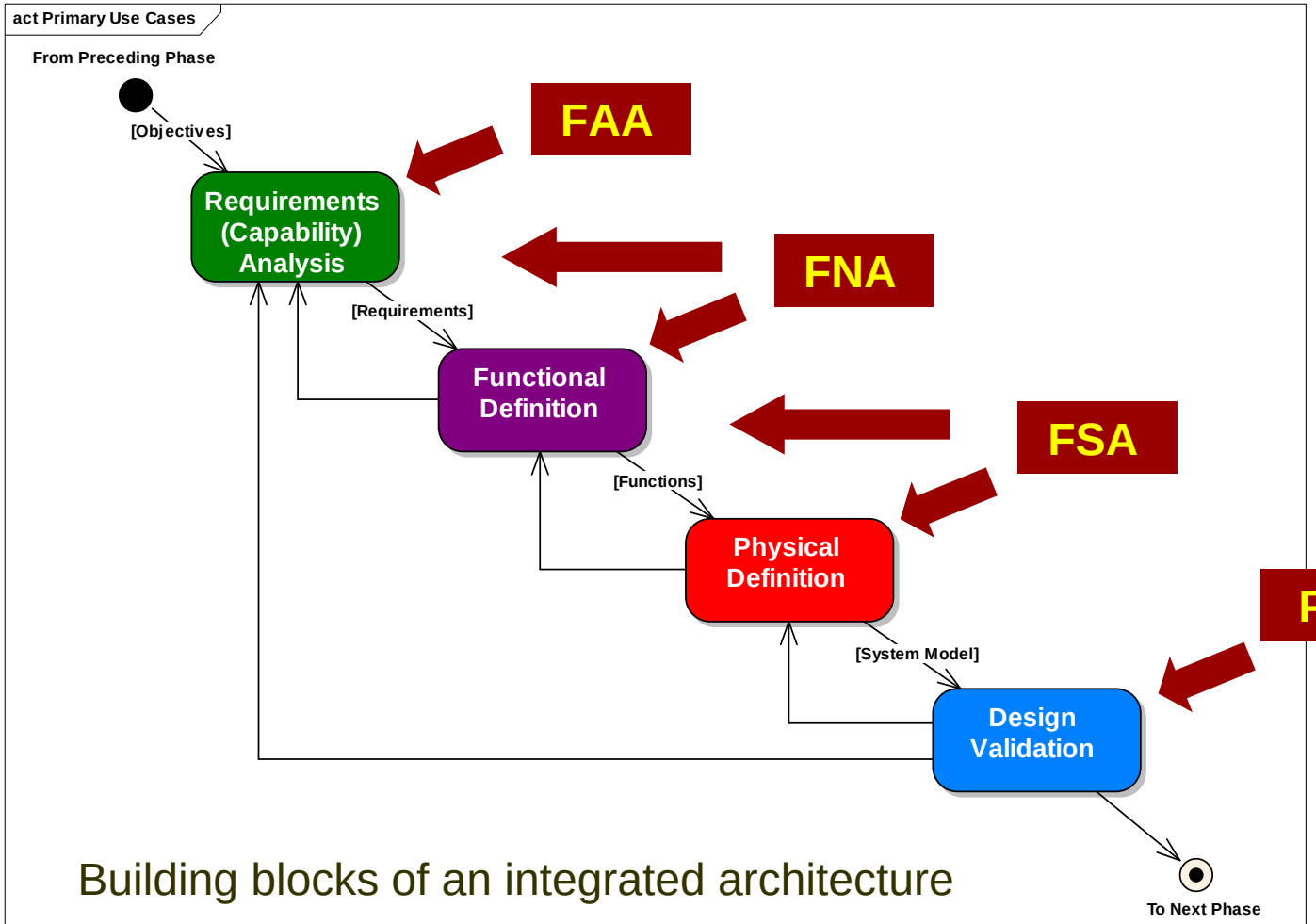
Transition from Capability to System

The Legacy System



DOTMLPF can also transition from "As-Is" to "To-Be"

Model-driven Approach Facilitates JCIDS



Adapted from Kossiakoff & Sweet "*Systems Engineering Principles and Practice*"

Building blocks of an integrated architecture

Benefits of Model-Driven Approach

- Traceable back to initial FAA and war fighting need
  - Changes to system requirements can be evaluated against the “to-be” capability identified during FAA, FNA, and FSA
    - Ensures solution implemented meets intent of JCIDS analysis
- One place to document entire system lifecycle from inception to deployment
  - Document rationale for decisions and analysis
  - Easily supports changes/updates to the model while maintaining historical information
  - Abstracts the complexities of the warfare system, the capability system, and associated elements such that a team can effectively grasp them
- Appropriate integrated architecture views can be generated
  - Operational views – requirements and functional model
  - System views – physical model
  - Technical views – requirements, physical models

Summary

- Model-driven SE will provide robust lifecycle system model
  - Provides integrated architecture
  - Supports initial capabilities assessment
  - Establishes framework for entire lifecycle: concept refinement, technology development, system development and demonstration, production and deployment, and operations and support phases
- Systems Engineering methodology enhances the JCIDS process
  - Models abstract complexities of modern warfare systems
- Comprehensive models provide for compilation of data needed to assess capabilities and comply with JCIDS

Models bridge the diverse knowledge domains of the warrior and the engineer

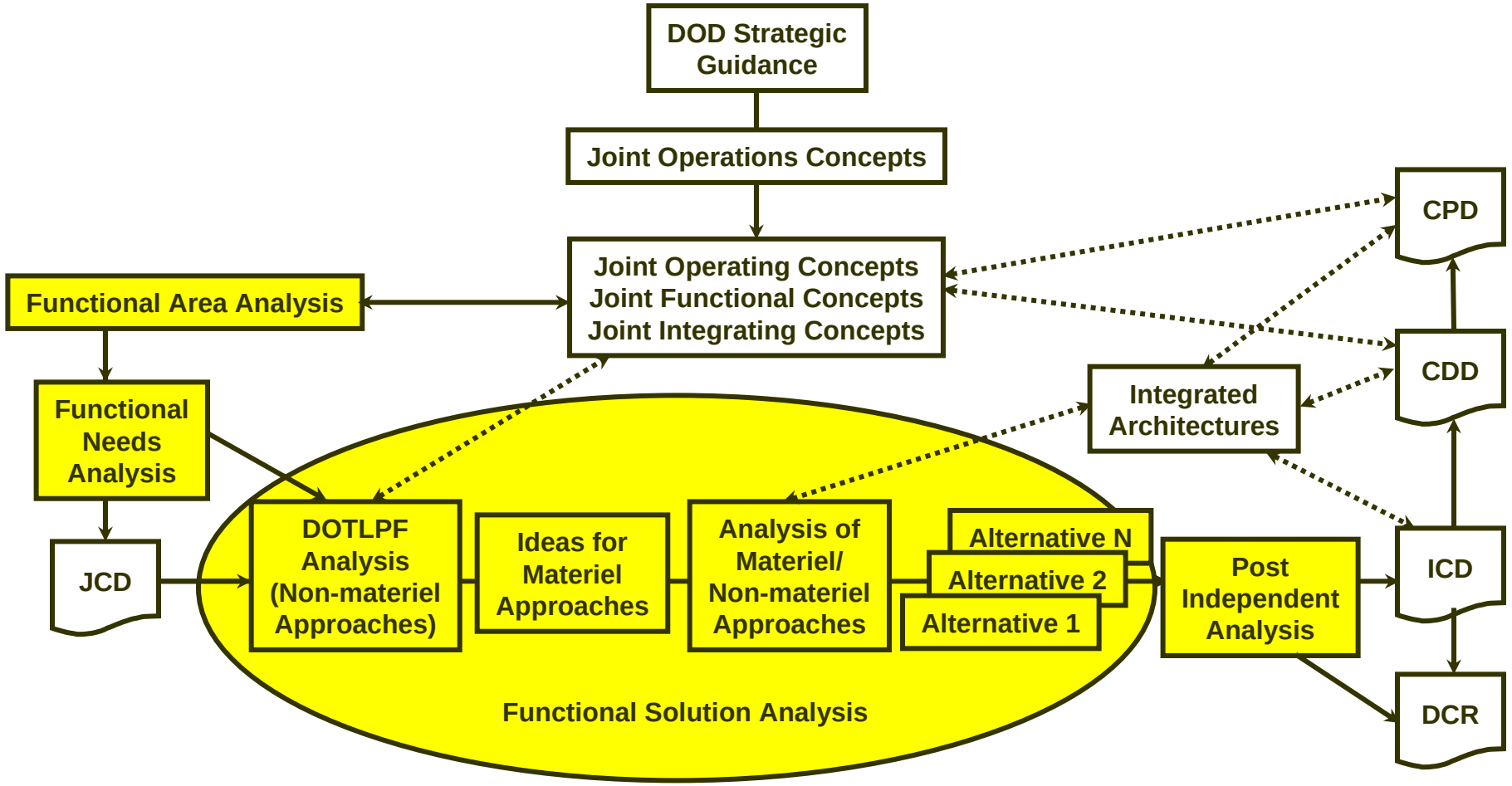
Functional Area Analysis (FAA)
Functional Needs Analysis (FNA)
Functional Solutions Analysis (FSA)

Dave Krueger
Chris Ryder
Contributions from Lee Kennedy and Bob Finlayson

NDIA
NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

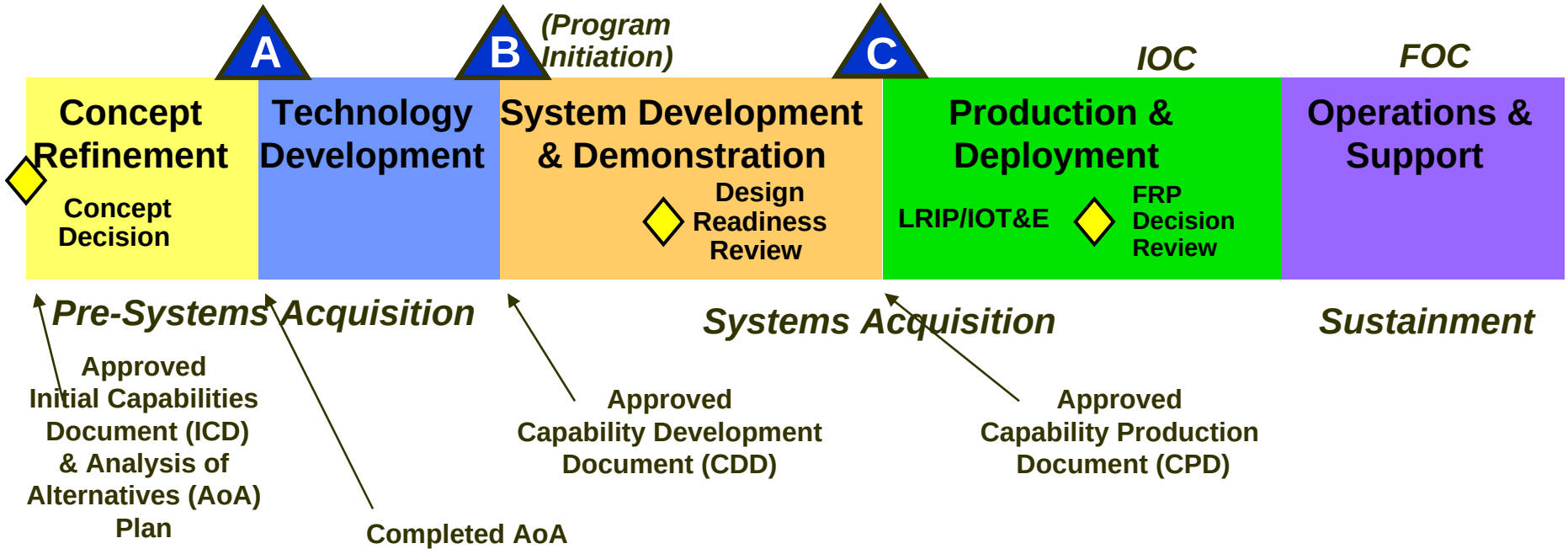
JCIDS Process*



*CJCSM 3170.01B

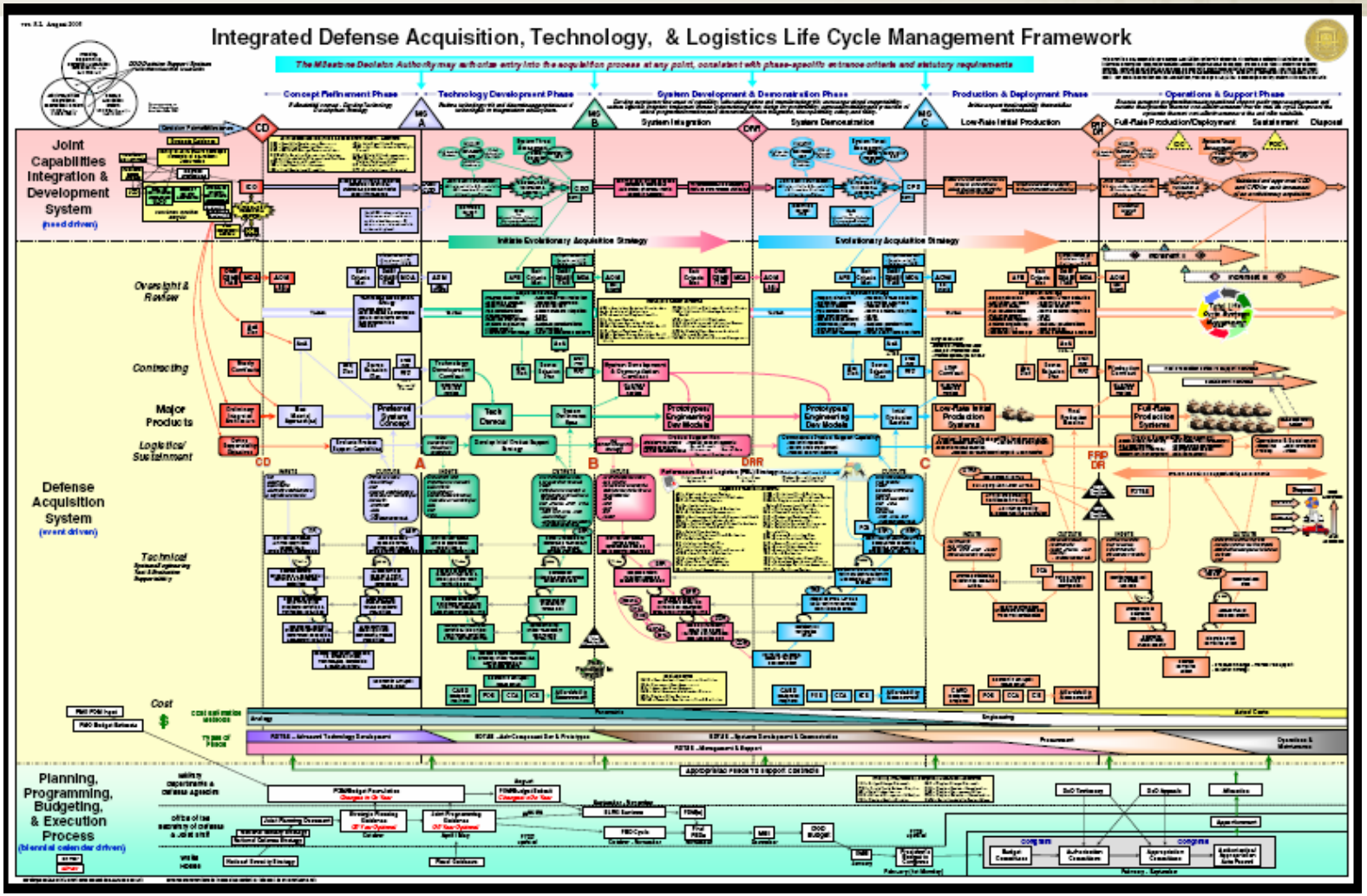
The Defense Acquisition Management Framework*

- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*



*DoDI 5000.2, 12 May 2003

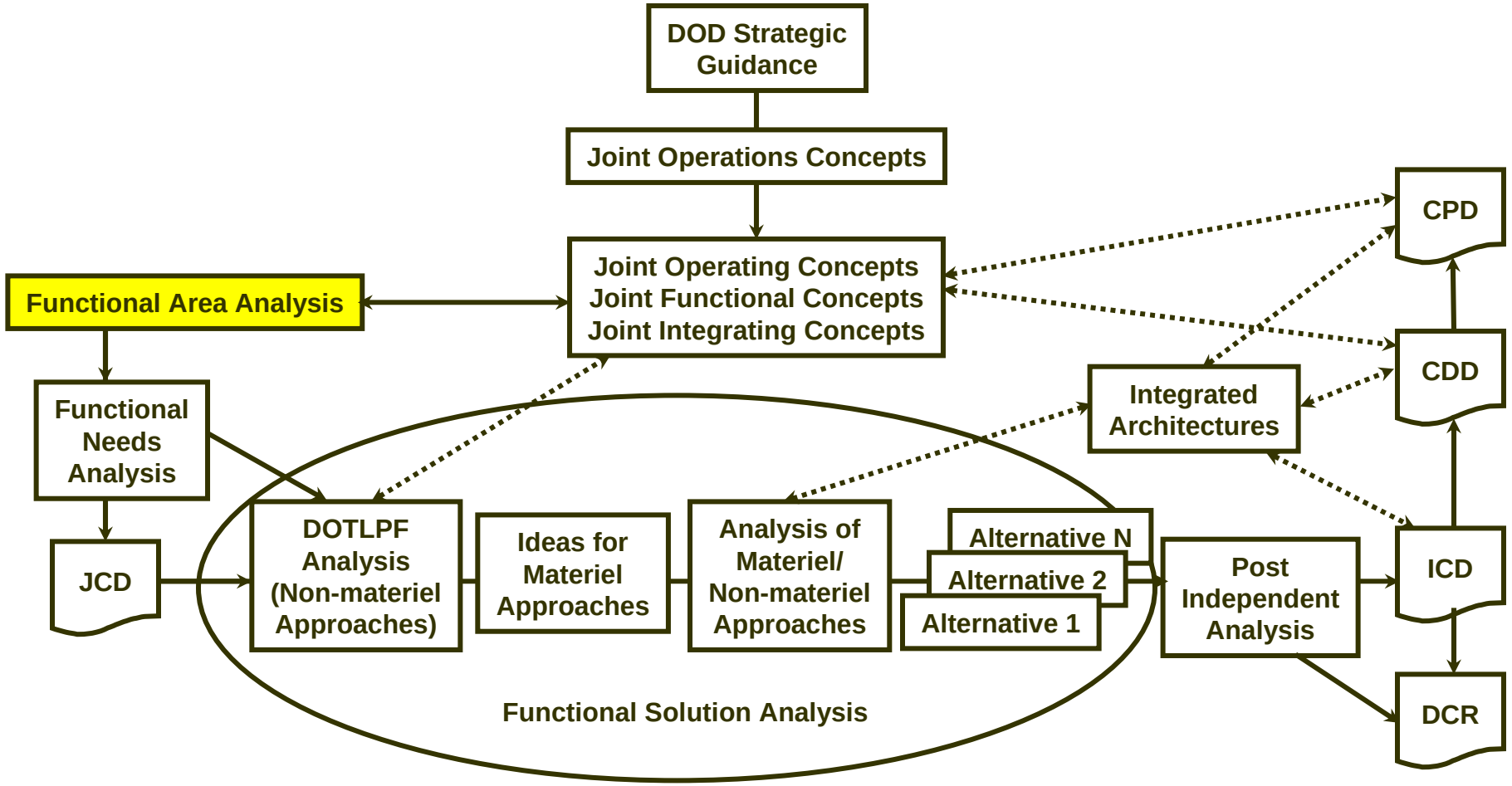
The Defense Acquisition Management Framework



Discussion Topics

- Perspective
- Introduction to the TBDA Case
- Functional area analysis (FAA)
- Functional needs analysis (FNA)
- Functional solutions analysis (FSA)
- Post independent analysis (PIA)
- Conclusion

JCIDS Process



CJCSM 3170.01B

Functional Area Analysis (FAA)

- Produces a list of capabilities across all functional areas necessary to achieve military objectives

- Capabilities
  - Operational tasks
  - Conditions
  - Standards (or measures of effectiveness)

- Input
  - National strategies, JOCs, JFCs, JICs, the Universal Joint Task List (UJTL)
  - Anticipated adversary capabilities

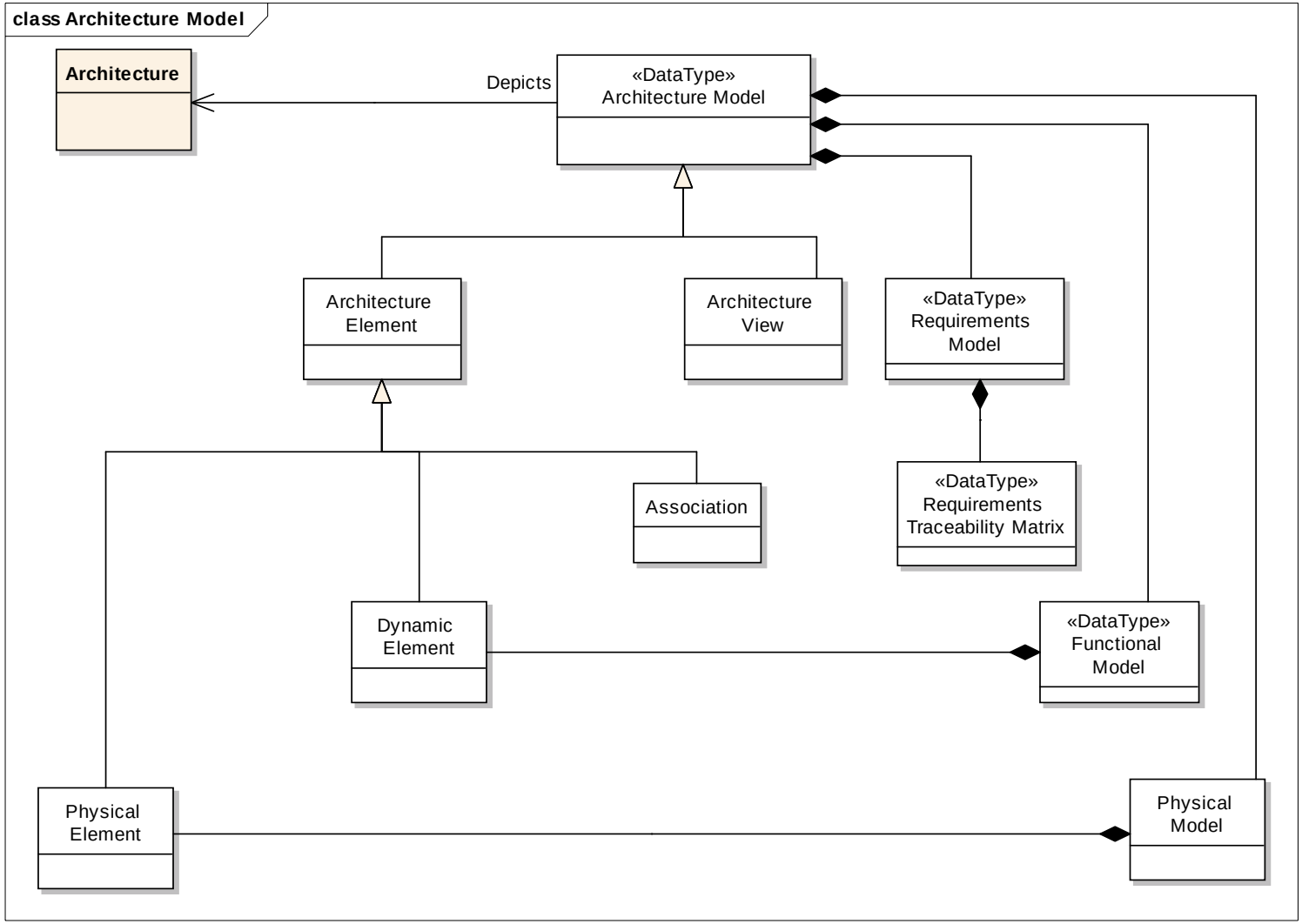
Defining the Problem Space

Defining the Problem Space

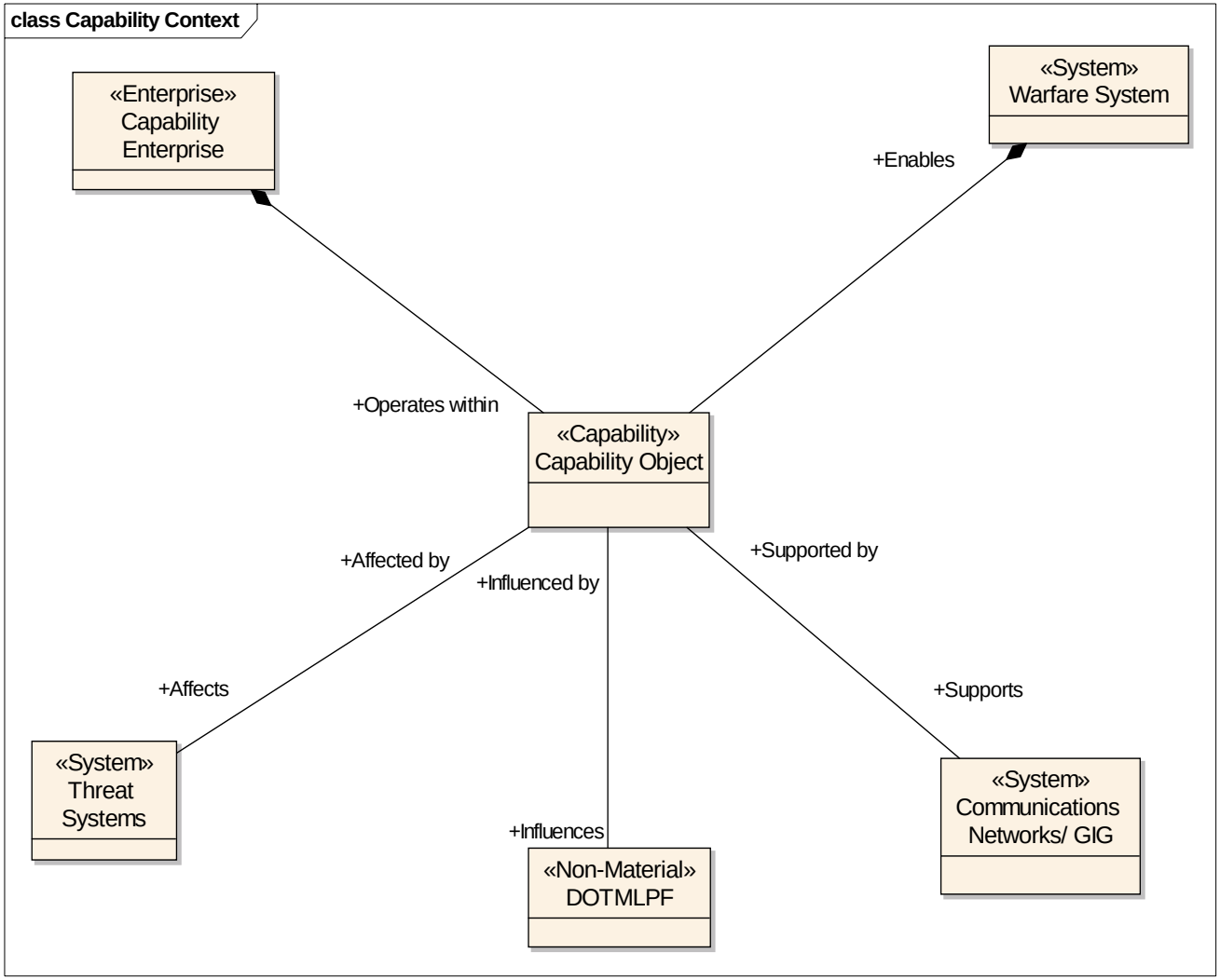
The Capability Context

- Understanding the Capability Enterprise
  - Environment
  - Enemy forces and systems
- Capability operations
- Capability operators (Warriors)
- Network requirements
- Capability command and control
  - Command authority
- Analysis of legacy Warfare Systems contributing to the Capability Object
- Preliminary Non-Materiel issues
  - DOTMLPF analysis primarily occurs during the FSA

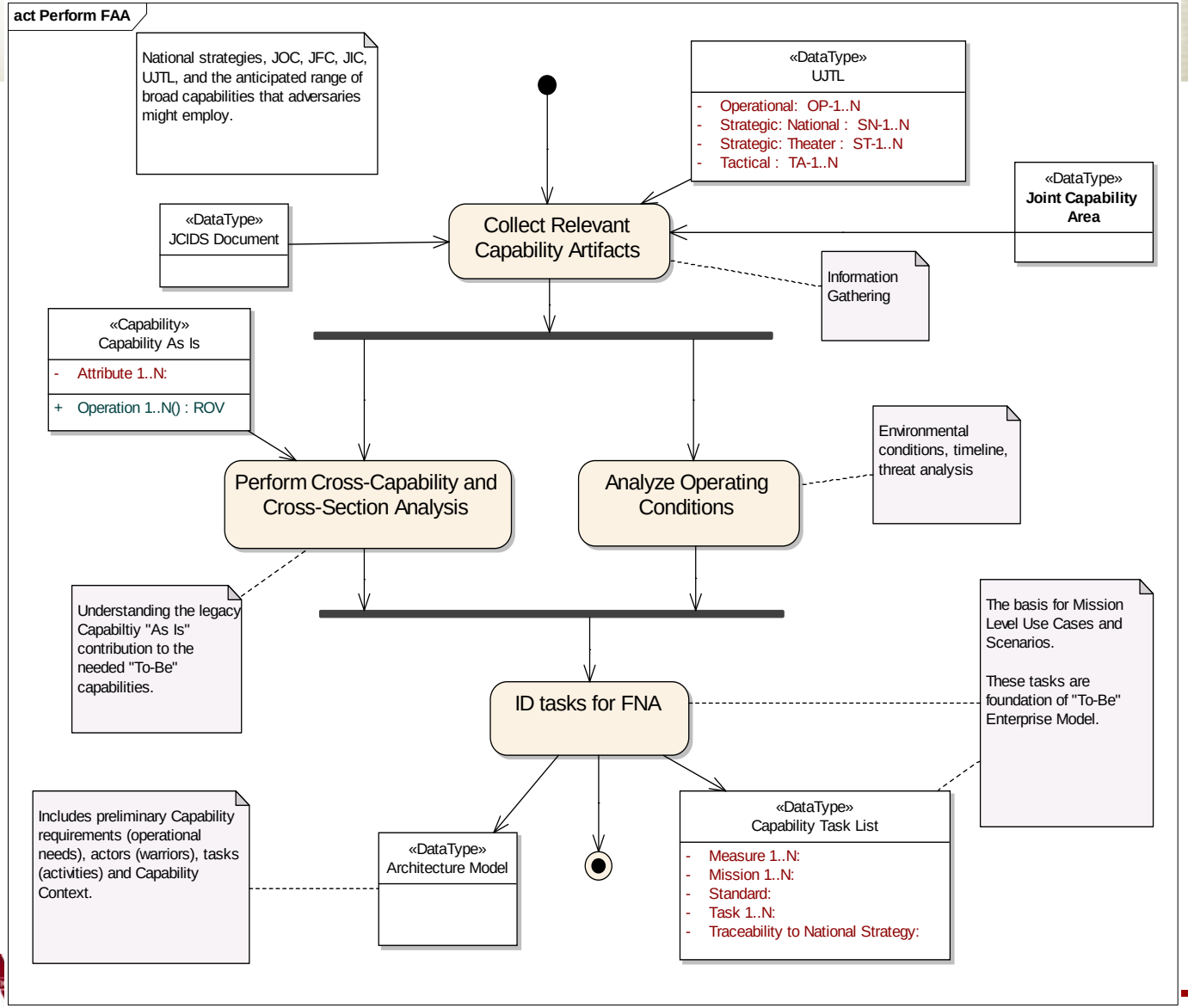
Architecture Meta-Model



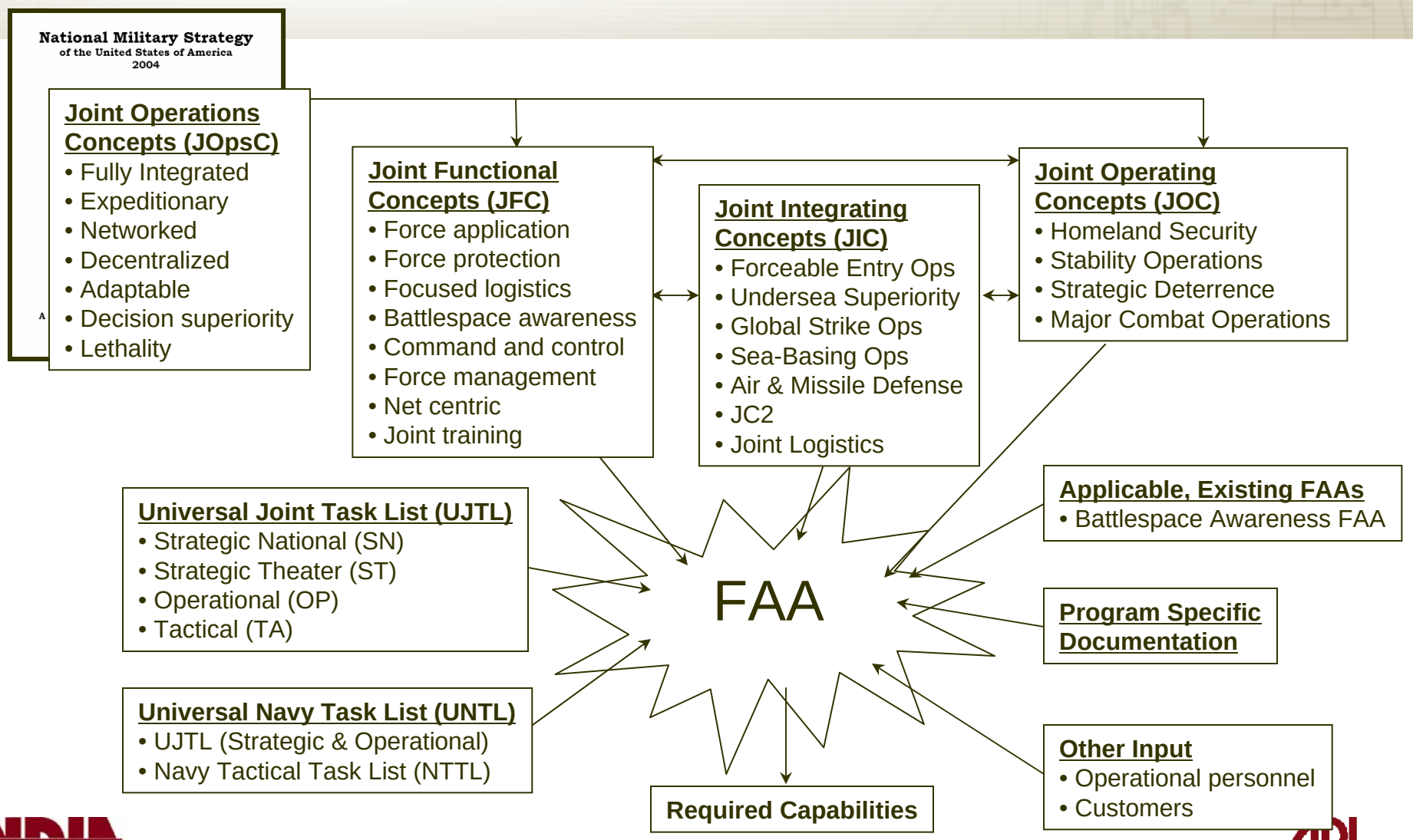
Capability Context
(Repeat from Model Driven SE Section)



FAA Activity Diagram



FAA Approach



Joint Operations Concepts (JOpsC)

- An overarching description of how the future Joint Force will operate across the entire range of military operations

- Attributes
  - Fully Integrated
  - Expeditionary
  - Networked
  - Decentralized
  - Adaptable
  - Decision superiority
  - Lethality

Too general for specific FAA development

Joint Integrating Concepts (JICs)

- **Description of how a Joint Force Commander will integrate capabilities to generate effects and achieve an objective**
  - **Forceable Entry Ops**
  - **Undersea Superiority**
  - **Global Strike Ops**
  - **Sea-Basing Ops**
  - **Air & Missile Defense**
  - **JC2**
  - **Joint Logistics**
- **Includes an illustrative CONOPS for a specific scenario and a set of distinguishing principles applicable to a range of scenarios**

Joint Operating Concepts (JOCs)

- Operational-level description of how the Joint Force Commander will operate and a foundation for defining military capabilities

- Operational context for JFC and JIC development
  - Homeland Security (HLS)
  - Stability Operations (SO)
  - Strategic Deterrence (SD)
  - Major Combat Operations (MCO)

Joint Functional Concepts (JFCs)

- Describes how the joint force will perform military functions across the range of military operations
- Functional areas
  - Force application
  - Force protection
  - Focused logistics
  - Battlespace awareness
  - Command and control
  - Force management
  - Net centric
  - Joint training

Functional Capability Board (FCB) for each functional area

Functional Capability Boards (FCB)

- Responsible for organization, analysis, and prioritization of capability needs proposals within their functional areas
- Provide oversight and assessment throughout JCIDS process
  - Reduce redundant analyses
  - Ensure consistency in capability definitions
  - Ensure approaches consider a broad range of possibilities
- Provides context briefing to JROC
  - Where capability proposal fits within functional area
- Make recommendations on validation and approval

Identify appropriate FCB and involve them in the analyses!

Battlespace Awareness JFC Capabilities

- **Operational**
  - **Command and control of BA assets**
  - **Execute collection**
  - **Exploitation and analysis**
  - **M&S, forecast**
  - **Manage knowledge**
- **Enabling**
  - **Integrate BA network**
  - **Infuse emergent technology**
  - **Recruit, retain, train**

Several capabilities IDed for each capability category, e.g.,

- Surveillance
- Cross cue
- Employ human resources
- Employ open source resources
- Measure & monitor environmental conditions

***"Functional Concept for Battlespace Awareness,"* 31 December 2003, p. 85.**

Battlespace Awareness FAA (Draft)

- **Defines Battlespace Awareness capabilities for each task and sub-task in each JOC**
  - **Homeland Security (HLS)**
  - **Stability Operations**
  - **Strategic Deterrence**
  - **Major Combat Operations (MCO)**

Tasks and sub-tasks for other JOCs not shown

1. Interdiction
   a. Kill 1st echelon forces
   b. Divert/delay follow-on forces
2. Ground operations
3. Air defense
4. Missile defense
5. JSEAD
6. Strike
7. Sea Strike Operations
8. Sea Shield Operations
9. Sea Basing Operations
10. Info Operations
11. Battlespace Awareness
12. Intent/I&W
13. I&W Specific Threat

UJTL and UNTL

- UJTL: "The Universal Joint Task List (UJTL), when augmented with the Service task lists, is a **comprehensive** integrated **menu** of **functional tasks, conditions, measures, and criteria** supporting all levels of the Department of Defense in executing the National Military Strategy."

- UNTL : "The UNTL tasks make up a comprehensive hierarchical structure. The UNTL task list is designed to be **comprehensive** while being **mutually exclusive**. When reviewing the levels of the hierarchy, the subordinate tasks will, in total, comprehensively, and without redundancy, define all activities involved in the next higher-level task."

Universal Joint Task List (UJTL)* Levels of War

- (SN) Strategic level - National military tasks
  - Accomplish objectives of national military strategy
- (ST) Strategic level - Theater tasks
  - Accomplish objectives of the theater and campaign strategy
- (OP) Operational level tasks
  - Accomplish objectives of subordinate campaigns and major operations
- (TA) Tactical level tasks - include joint/interoperability tactical tasks and the applicable Service tasks
  - Accomplish objectives of battles and engagements

** CJCSM 3500.04C, "Universal Joint Task List (UJTL)," 1 July 2002*

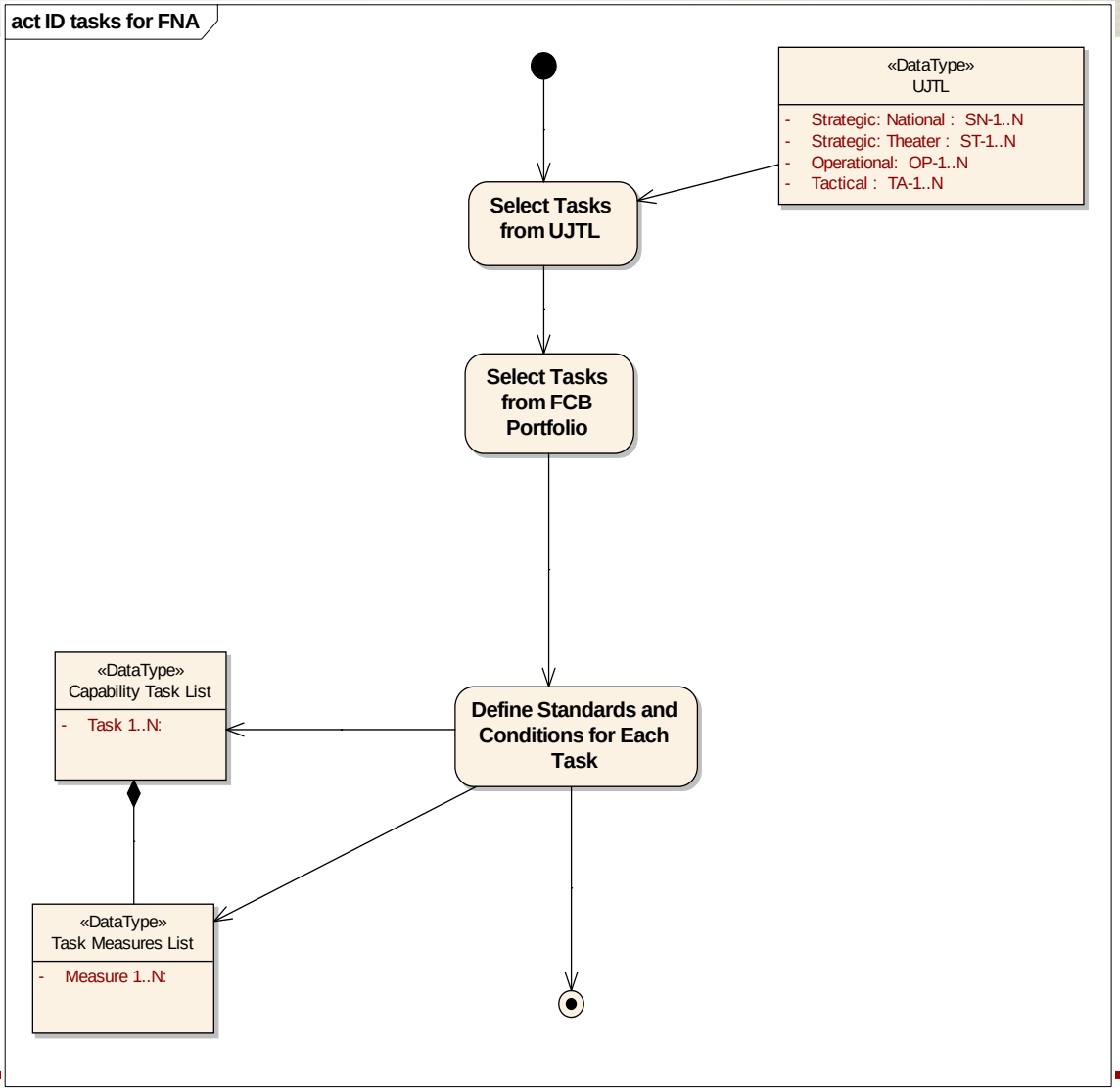
UNTL
Example Hierarchy

To obtain, by various detection methods, information about the activities of an enemy or potential enemy or tactical area of operations. This task uses surveillance to systematically observe the area of operations by visual, aural, electronic, photographic, or other means. This includes development and execution of search plans.

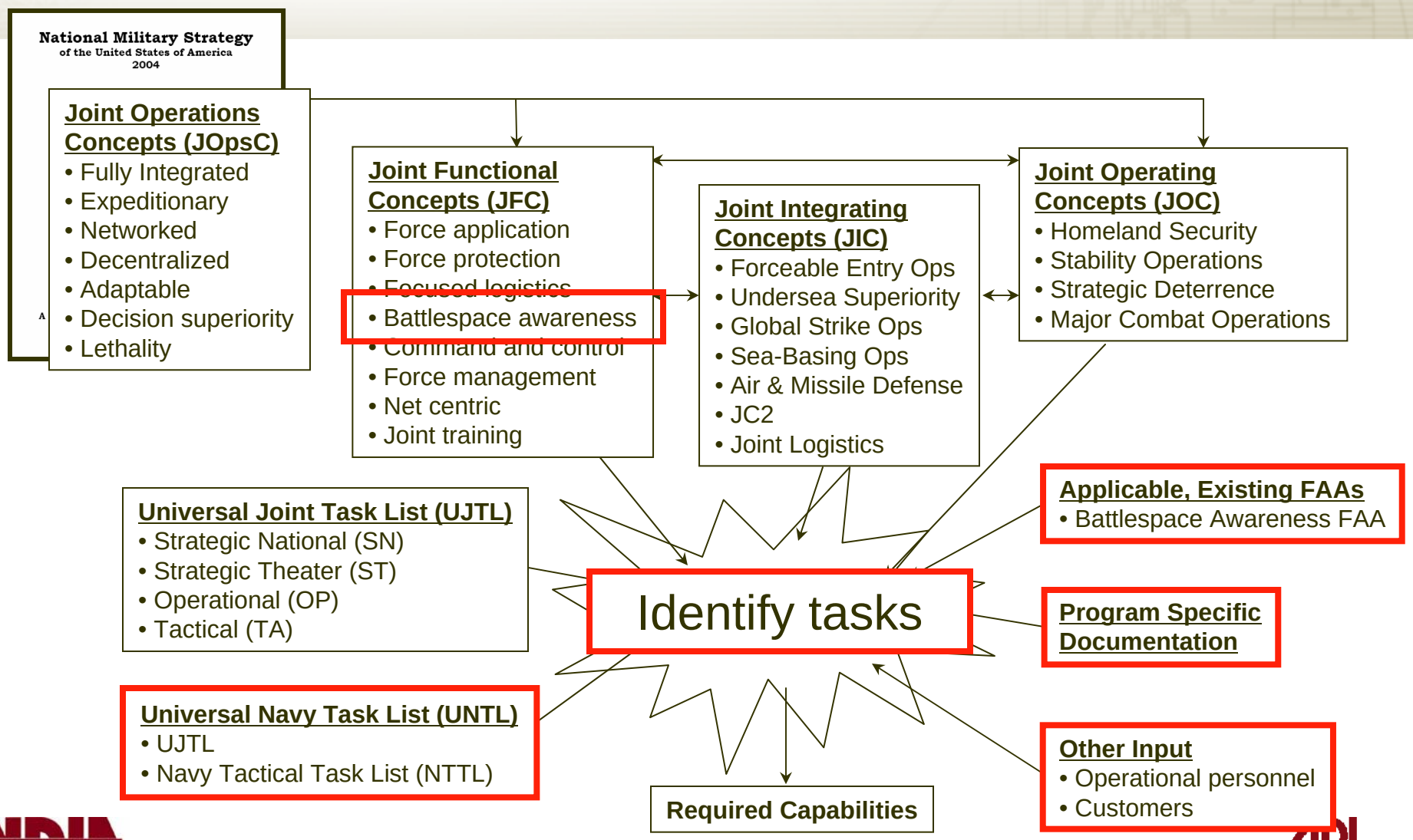
NTA	Navy Tactical
NTA 1	Deploy Forces/Conduct Maneuver
NTA 2	Develop Intelligence
NTA 2.1	Plan and Direct Intelligence Operations
NTA 2.2	Collect Data and Intelligence
NTA 2.2.1	Collect Target Information
NTA 2.2.2	Collect Tactical Intelligence on Situation
NTA 2.2.3	Perform Tactical Reconnaissance and Surveillance
NTA 2.2.4	Assess Tactical Environment
NTA 2.3	Process and Exploit Collected Info/Intelligence
NTA 2.3.1	Conduct Technical Processing and Exploitation
NTA 2.3.2	Correlate Information
NTA 2.4	Produce Intelligence
NTA 2.5	Disseminate and Integrate Intelligence
NTA 3	Employ Firepower
NTA 4	Perform Logistics and Combat Service Support
NTA 5	Exercise Command and Control
NTA 6	Protect the Force

To associate and combine data on a single subject to improve the reliability or credibility of the information. This task includes collating information (identifying and grouping related items of information for critical comparison).

Identify Tasks for FNA



Identify Tasks



Select Tasks from UJTL & UNTL

NTA	Navy Tactical	Y
NTA 1	Deploy Forces/Conduct Maneuver	P
NTA 2	Develop Intelligence	Y
NTA 2.1	Plan and Direct Intelligence Operations	N
NTA 2.2	Collect Data and Intelligence	Y
NTA 2.2.1	Collect Target Information	Y
NTA 2.2.2	Collect Tactical Intelligence on Situation	Y
NTA 2.2.3	Perform Tactical Reconnaissance and Surveillance	Y
NTA 2.2.4	Assess Tactical Environment	Y
NTA 2.3	Process and Exploit Collected Info/Intelligence	Y
NTA 2.3.1	Conduct Technical Processing and Exploitation	Y
NTA 2.3.2	Correlate Information	Y
NTA 2.4	Produce Intelligence	Y
NTA 2.5	Disseminate and Integrate Intelligence	P
NTA 3	Employ Firepower	P
NTA 4	Perform Logistics and Combat Service Support	N
NTA 5	Exercise Command and Control	P
NTA 6	Protect the Force	P

Select Tasks from FCB Portfolios

Battlespace Awareness Tasks		Applicable
Command and Control of BA Assets	**Synchronize ISR with operations**	Y
	Task, dynamically re-task and monitor assets	N
Execute Collection	**Surveillance**	Y
	Cross cue	Y
	Employ human resources	Y
	Employ open source resources	N
	Measure and monitor environmental conditions	P
Exploit and Analyze	**Recognize targets**	Y
	Distribute processing	N
	Information fusion	Y
	Enable analyst collaboration	N
	Defeat denial and deception	P
Model, Simulate, Forecast/Predict	**Predictive analysis**	N
	Integrate adversary and friendly information	N
Manage Knowledge	**Smart pull/push information**	Y
	Share plan visibility	N
	Content management	N

Define Conditions and Standards for Each Task

- **Conditions - a variable of the environment that affects performance of a task**
  - **Physical: land, sea, air, space**
  - **Military: mission; forces; C3; intelligence; deployment, movement, and maneuver; firepower; protection; sustainment; threat; conflict**
  - **Civil: political policies, culture, economy,**
- **Standard - the minimum proficiency required in the performance of a task**
  - **Measure - Quantitative or qualitative basis for describing the quality of task performance**
  - **Criterion - A critical, threshold, or specified value of a measure**
- **Sources**
  - **UJTL/UNTL**
  - **Design Reference Mission (DRM)**
  - **Subject Matter Experts (SMEs)**

Example Conditions From UNTL

- **C 1.0 PHYSICAL ENVIRONMENT**
  - **C 1.1 LAND**
    - **C 1.1.1 Terrain**
      - **C 1.1.1.1 Terrain Relief**
      - **C 1.1.1.2 Terrain Elevation**
      - **C 1.1.1.3 Terrain Slope**
      - **C 1.1.1.4 Terrain Firmness**
      - **C 1.1.1.5 Terrain Traction**
      - **C 1.1.1.6 Vegetation**
        Plants, trees, and shrubs.
        ***Descriptors*: Jungle (rainforest, canopied); Dense (forested); Light (meadow, plain); Sparse (alpine, semi-desert); Negligible (arctic, desert).**
      - **C 1.1.1.7 Terrain Relief features**
    - **C 1.1.2 Geological Features**
    - **C 1.1.3 Man-Made Terrain Features**
    - **Etc.**

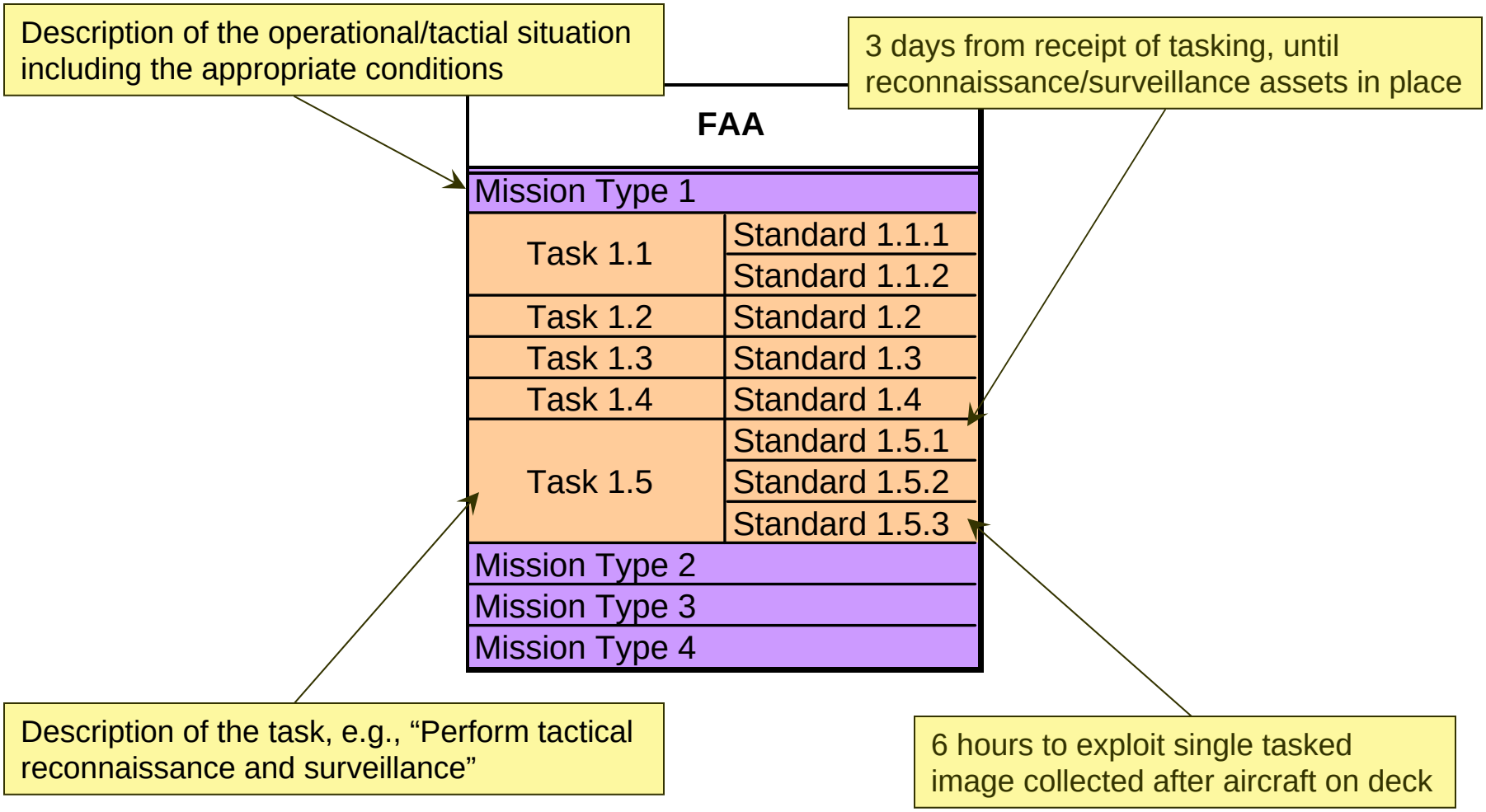
Example Measures

NTA 2.2.3 Perform Tactical Reconnaissance and Surveillance

To obtain, by various detection methods, information about the activities of an enemy or potential enemy or tactical area of operations. This task uses surveillance to systematically observe the area of operations by visual, aural, electronic, photographic, or other means. This includes development and execution of search plans.

Units	Measure
Days	**From receipt of tasking, until reconnaissance/surveillance assets in place**
Percent	**Of collection requirements fulfilled by reconnaissance/surveillance assets**
Percent	**Of time able to respond to collection requirements**
Hours	**To respond to emergent tasking**
Percent	**Operational availability of tactical aircraft reconnaissance systems**
Time	**To exploit single tasked image collected after aircraft on deck**

FAA Results


Description of the operational/tactial situation including the appropriate conditions
3 days from receipt of tasking, until reconnaissance/surveillance assets in place
FAA
Mission Type 1
Task 1.1
Standard 1.1.1
Standard 1.1.2
Task 1.2
Standard 1.2
Task 1.3
Standard 1.3
Task 1.4
Standard 1.4
Task 1.5
Standard 1.5.1
Standard 1.5.2
Standard 1.5.3
Mission Type 2
Mission Type 3
Mission Type 4
Description of the task, e.g., “Perform tactical reconnaissance and surveillance”
6 hours to exploit single tasked image collected after aircraft on deck

FAA Artifacts

- First iteration of Architecture Model
  - Capability Requirements Model
  - Capability Context Diagram
    - Block Definition Diagram
  - Identification of actors within the Capability Enterprise
    - Block Definition Diagram
  - Capability tasks depicted in Use Case Diagram
    - And Activity Diagram as appropriate

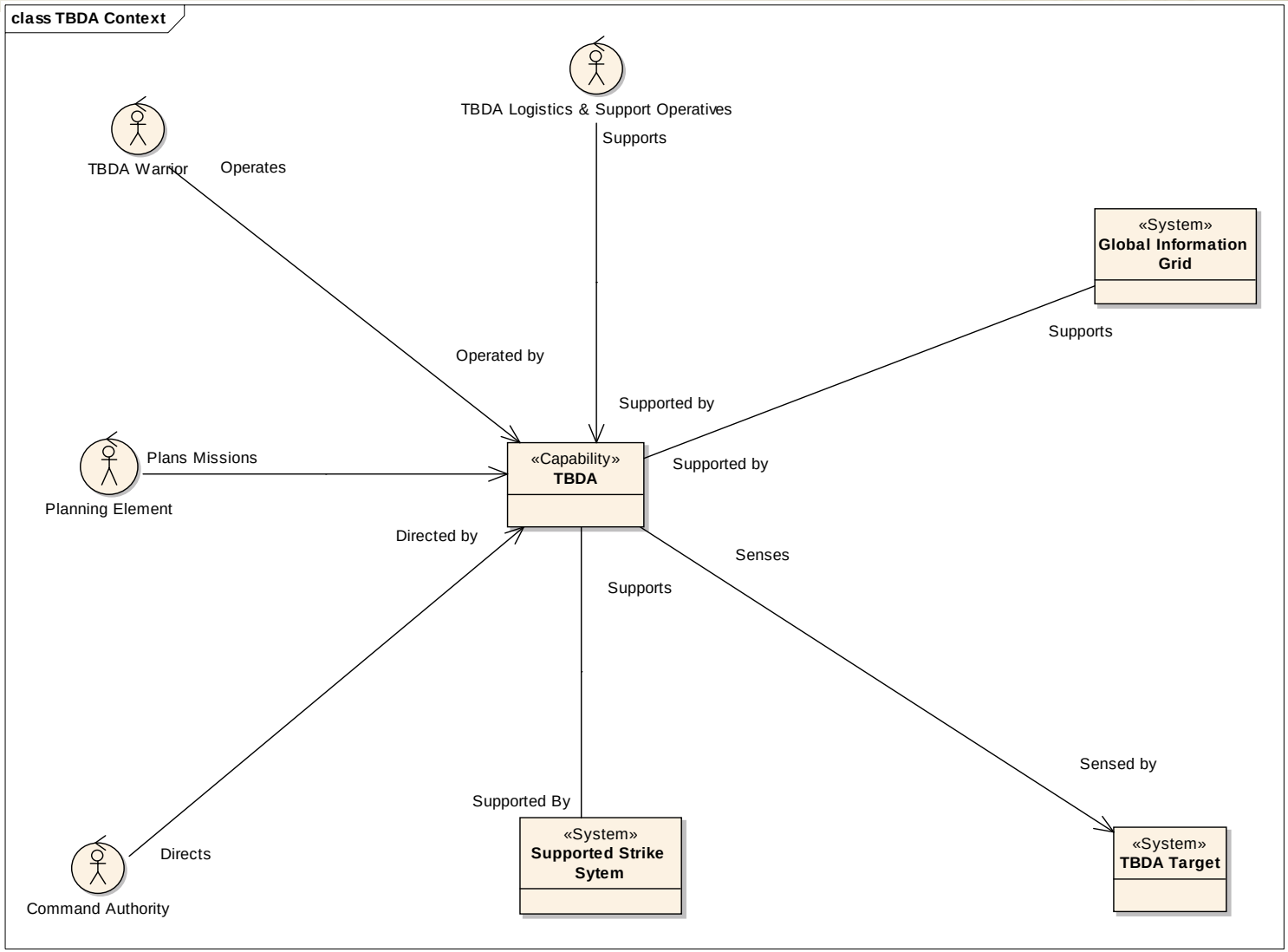
FAA Artifacts

- First Iteration of Architecture Model
  - Initial information exchanges and data elements
    - Sequence Diagram
  - Tasks can be captured as SysML Blocks that include task standards
    - Task attributes (measures)
    - Results of Value (Post-Conditions that determine success/failure)
- Capability Task List
  - Capability tasks trace to model elements, including capability requirements

TBDA FAA

- Define the operational enterprise for the TBDA that will:
  - Establish measurable capability needs for targeting and surveillance
  - Specify the pertinent operations for targeting and surveillance that will capture the correct capability tasks
  - Comprehend the “Capability Enablers”, those “things” that provide pieces of the overall capability
    - Including initial review of legacy systems
    - As well as non-materiel contributors
  - Who are the beneficiaries of the capability
  - What are the potential data elements, information exchanges and interfaces
  - Verify that the capability is required and that it is captured correctly

TBDA Context



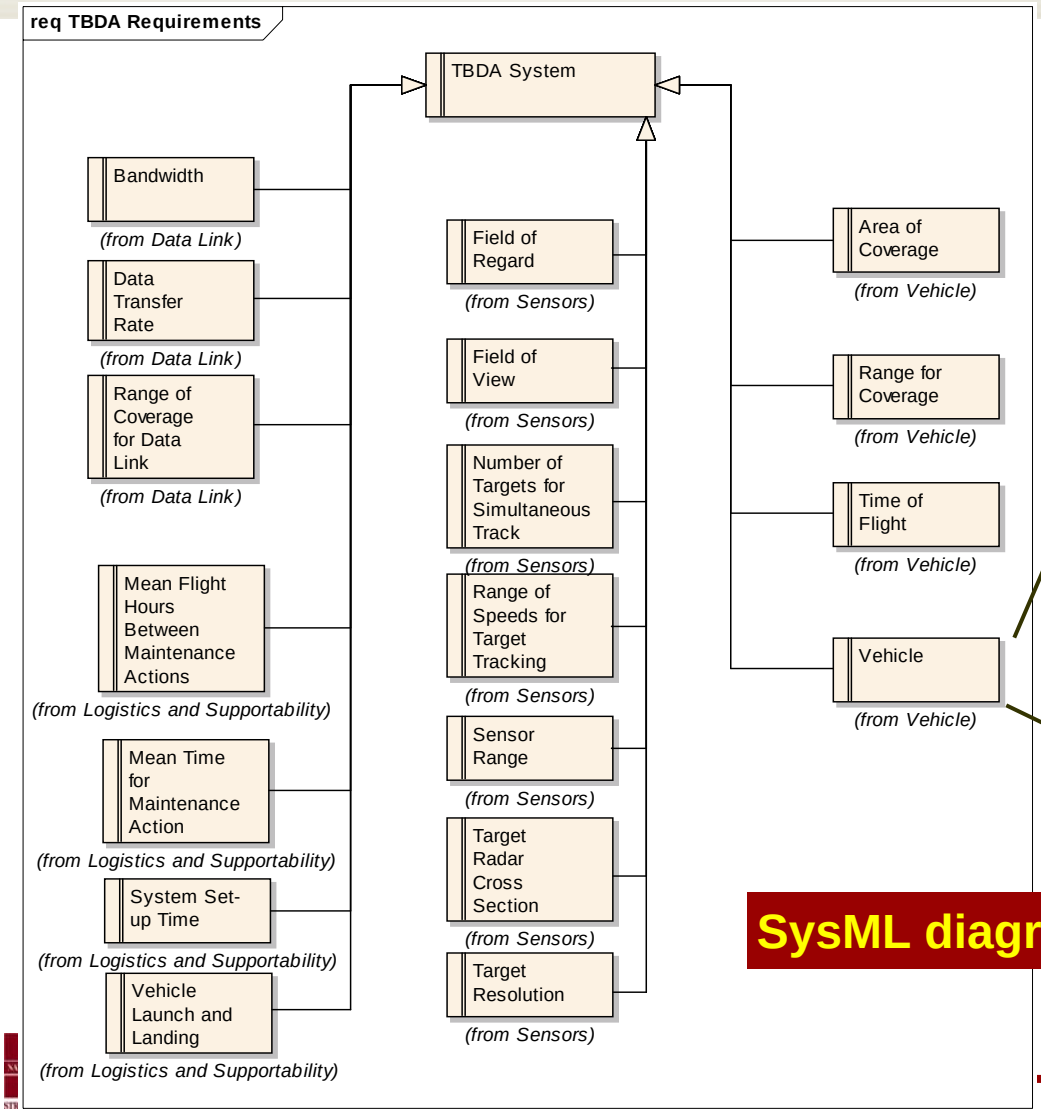
TBDA Context

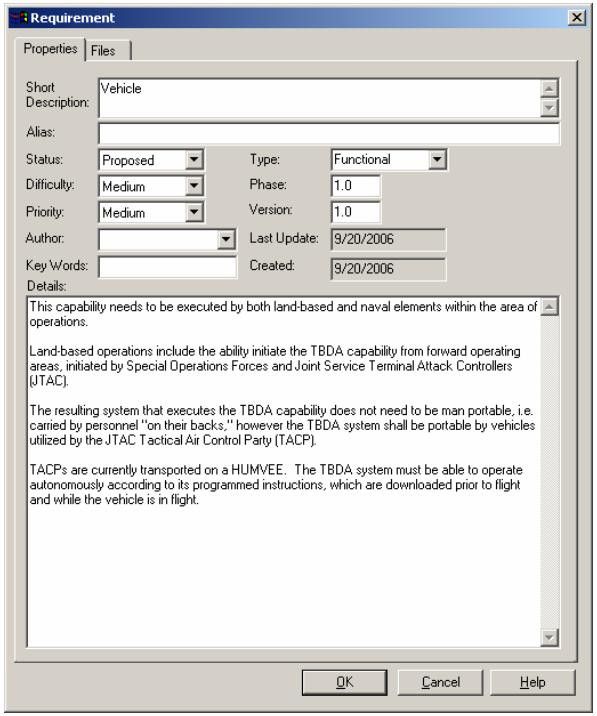
- At this point in the analysis, the TBDA :
  - Is under the direction of some Command Authority
  - Senses a generic class of targets
  - Interfaces with the Global Information Grid
  - Operated by Warriors
  - Supported and maintained by Warriors
- It is highly probable that he Capability Context will be modified throughout the FAA (and follow-on analysis phases)

TBDA Capability Elements
(The FAA Requirements Model)

- Four basic needs categories
  - Networking/ Data Link
    - TBDA Information must "get somewhere"
  - Sensors
    - Some "thing" must capture TBDA information
  - Vehicle
    - The capability must be deployed within a defined battespace
  - Supportability and Logistics
    - "Professionals think Logistics"
- Requirements can be captured using data bases and graphical tools
  - Requirements Traceability Matrix (RTM)
  - SysML Requirements Diagram
  - These artifacts must be "tightly coupled"

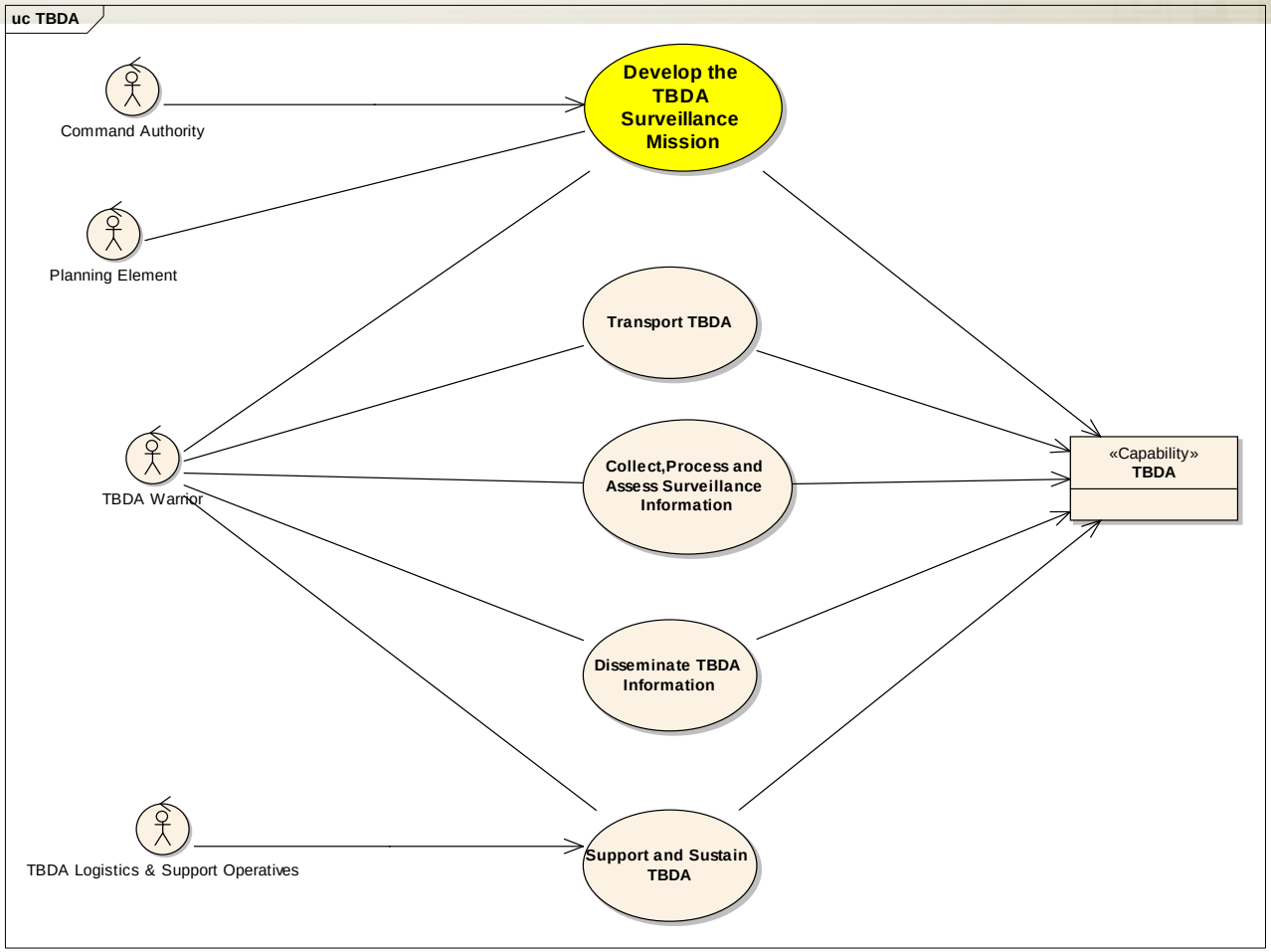
TBDA FAA Requirements Diagram





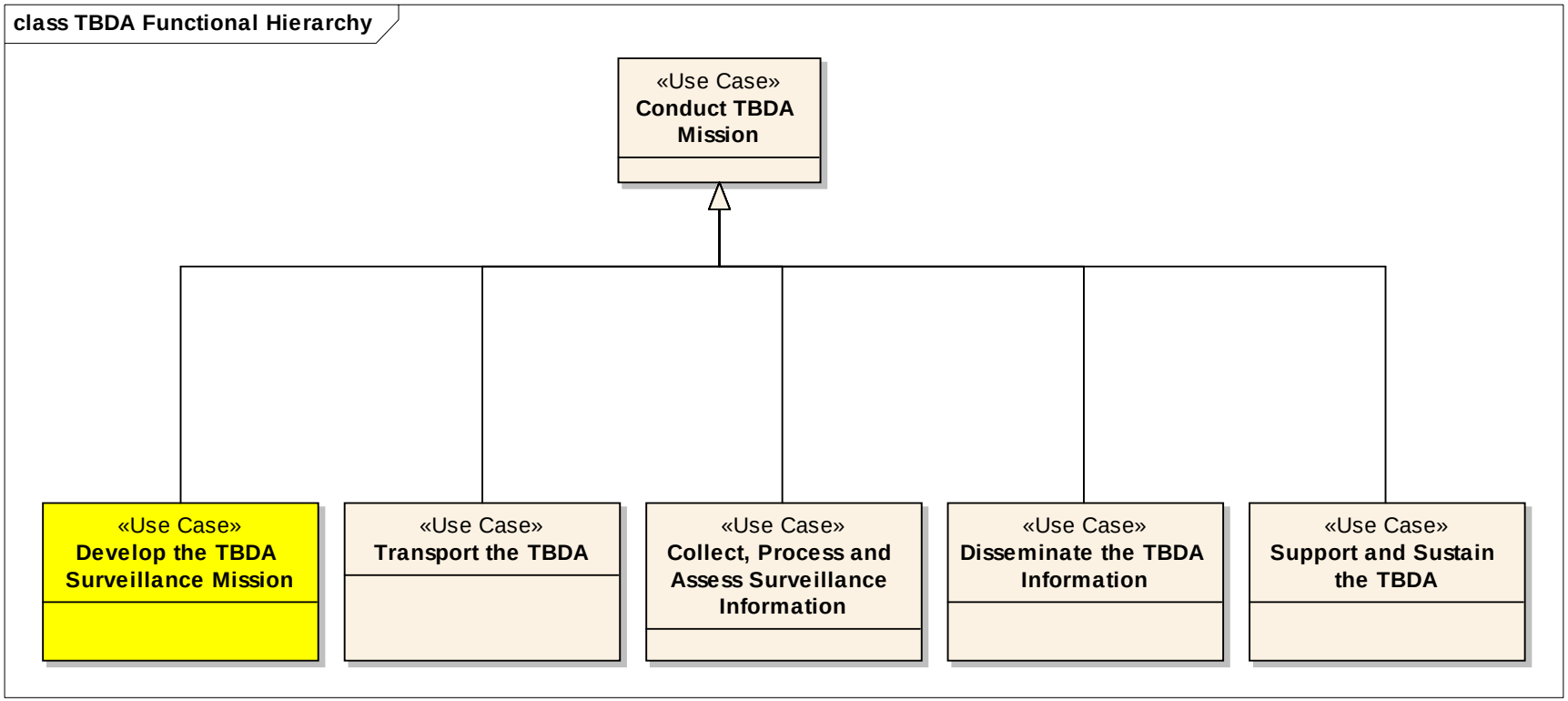
SysML diagrams supported by robust database

TBDA Fundamental Operations



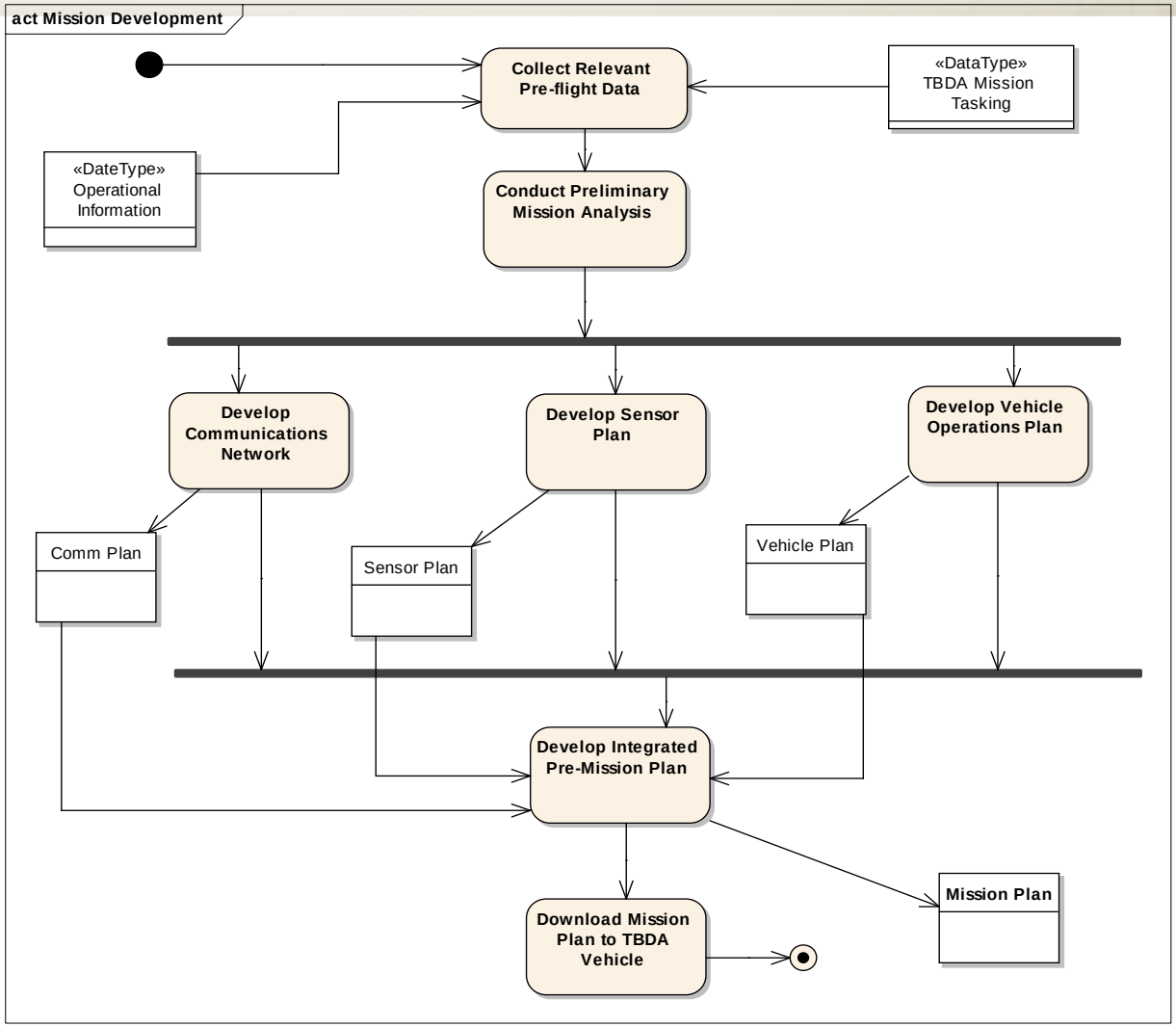
SysML Use Case Diagram Captures Basic Functionality Performed by Actors

Fundamental Operations Function Tree

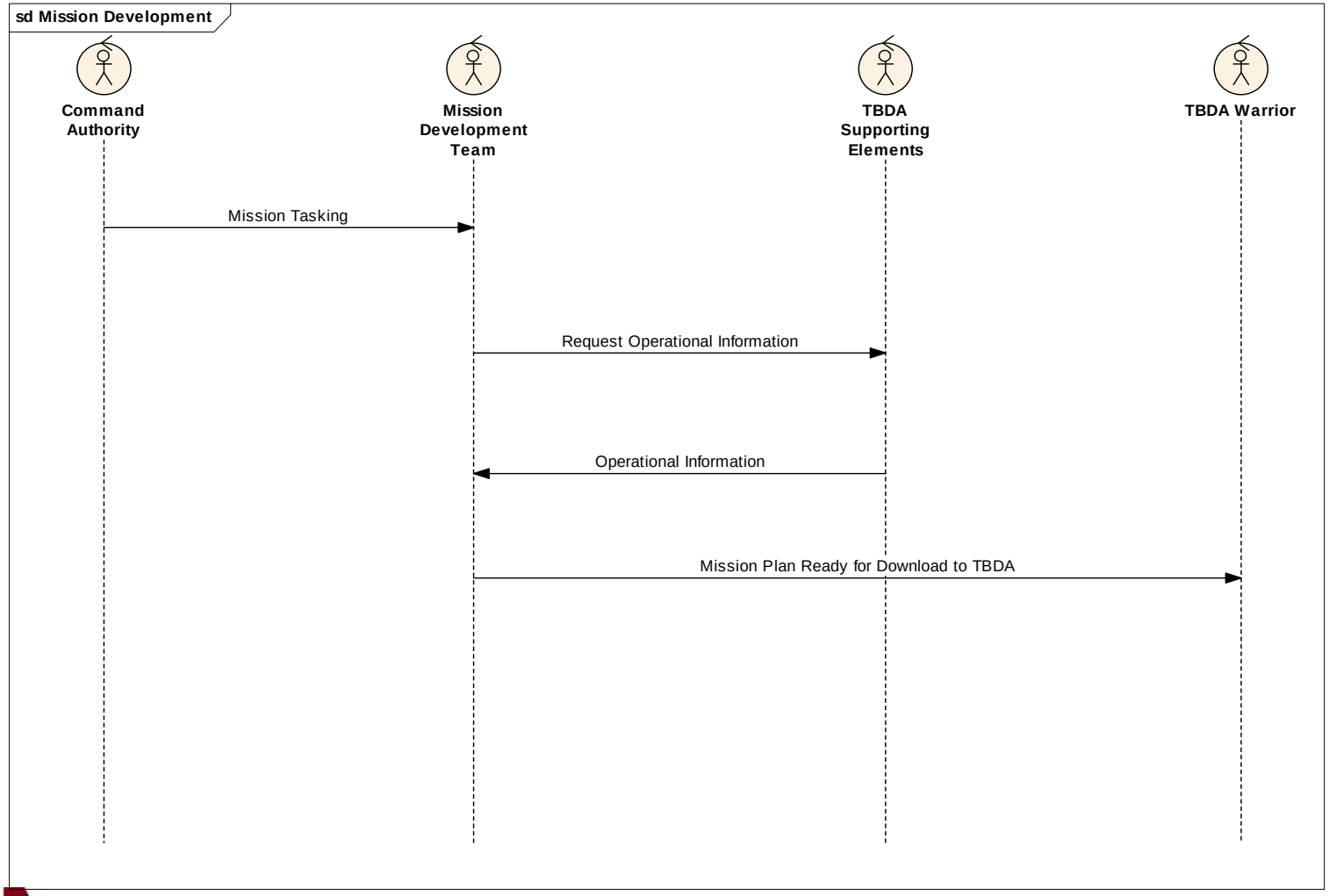


TBDA Functional Decomposition

(Develop the TBDA Mission)



TBDA Functional Analysis
(Initial Data Exchanges)

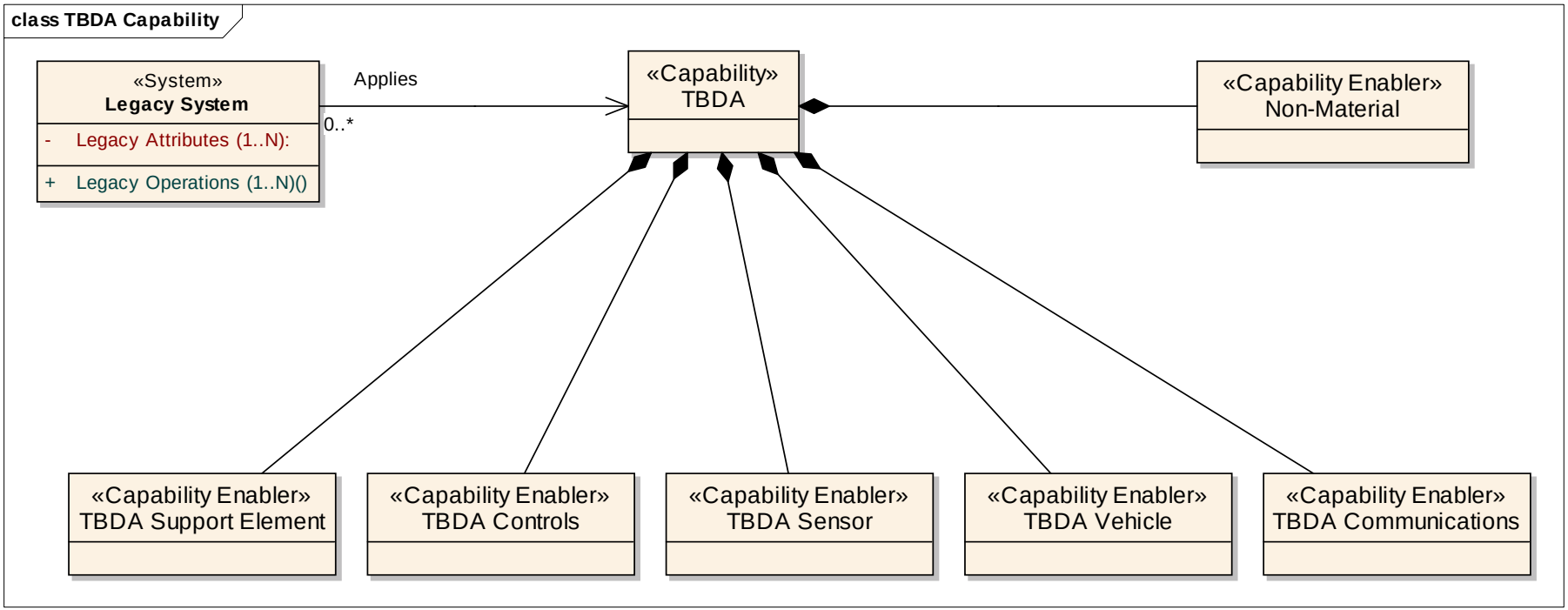


SysML Diagrams Supporting Functional Analysis

- Activity Diagram
  - Depicts functional elements as activities
    - Activities create Data Elements that are consumed in subsequent activities or use cases
    - Team can assess initial data requirements
    - Data Element is most often the Result of Value (ROV)
  - Modified to show "who" is performing the activities via "swim lanes"
- Sequence Diagram (aka Interaction Diagram)
  - Depicts sequence of information exchanges
    - Sending and receiving nodes
  - Analysis team should be able to get an initial understanding of interface requirements

Activities and Use Cases Trace to UNTL Tasks

TBDA FAA Logical Elements



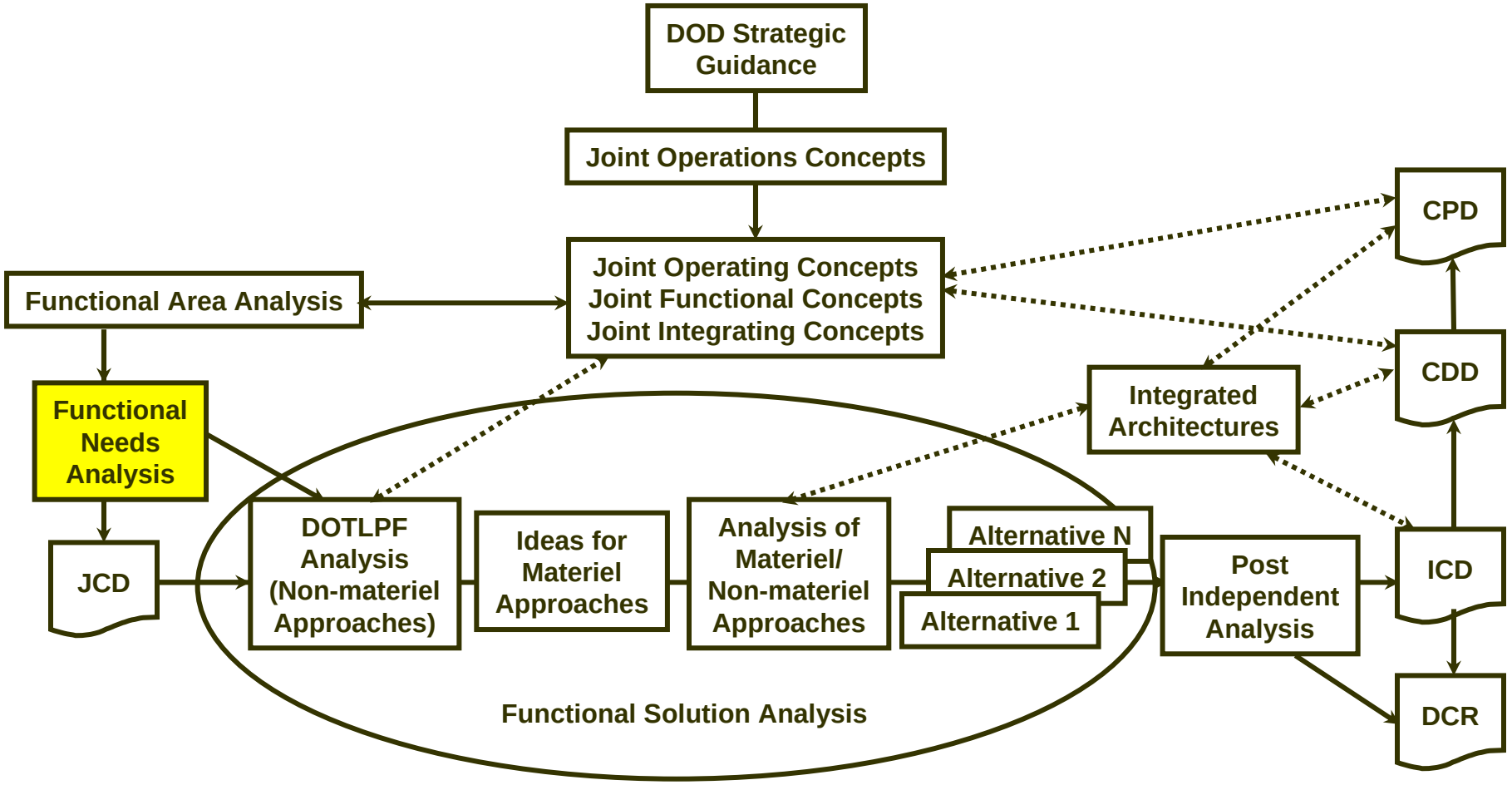
TBDA FAA Block Definition Diagram

- Even during the FAA, some “Capability Enablers” can be logically deduced
  - As analysis progresses, the attributes for these Enablers will be defined as well as functionality assigned to those elements
- Acknowledged that there are some non-materiel contributors
- Initial review of legacy systems
  - Further studied during FNA

TBDA FAA Architectural Model

- Captured the operational need through a SysML Requirements Diagram
  - Along with RTM
  - SE Method: Requirements Analysis
- Identified basic functionality
  - Will contribute to UJTL task assessment
  - Initially capture potential data elements and interfaces
  - Help generate Capability Task List for the FNA
  - SE Method: Functional Definition
- Identified Capability Enablers
  - Along with “first look” contributions by Legacy Systems and non-materiel elements
  - SE Method: Physical Definition
- Each of the basic functions and Capability Enablers must trace to the capability requirements listed in the Statement of Operational Need
  - SE Method: Design Validation

JCIDS Process



CJCSM 3170.01B

Functional Needs Analysis (FNA)

- Assess current and programmed warfighting systems
  - Can they deliver the capabilities identified in the FAA
  - Uses conditions from FAA
  - Uses standards from the FAA as the “measuring stick”

- Output
  - List of capability gaps or shortfalls
    - Relative priority
    - Timeframe for required solutions
  - Identify redundancies in capabilities that reflect inefficiencies.

Determines gaps in planned capabilities

FNA Activities

- Activity/ Task Mapping
  - Functional decomposition including measurable results of value
  - Assignment of functions to logical elements
  - Refinement of capability measures
    - Forwarded to JROC for approval
- Resource allocation
  - Contribution of legacy Warfare System capabilities
- Trades Analyses
  - Cost, schedule and performance constraints
  - Task alternatives and weighting
- Interoperability assessment
  - Refinement of information exchanges and date elements

FNA Functional Analysis

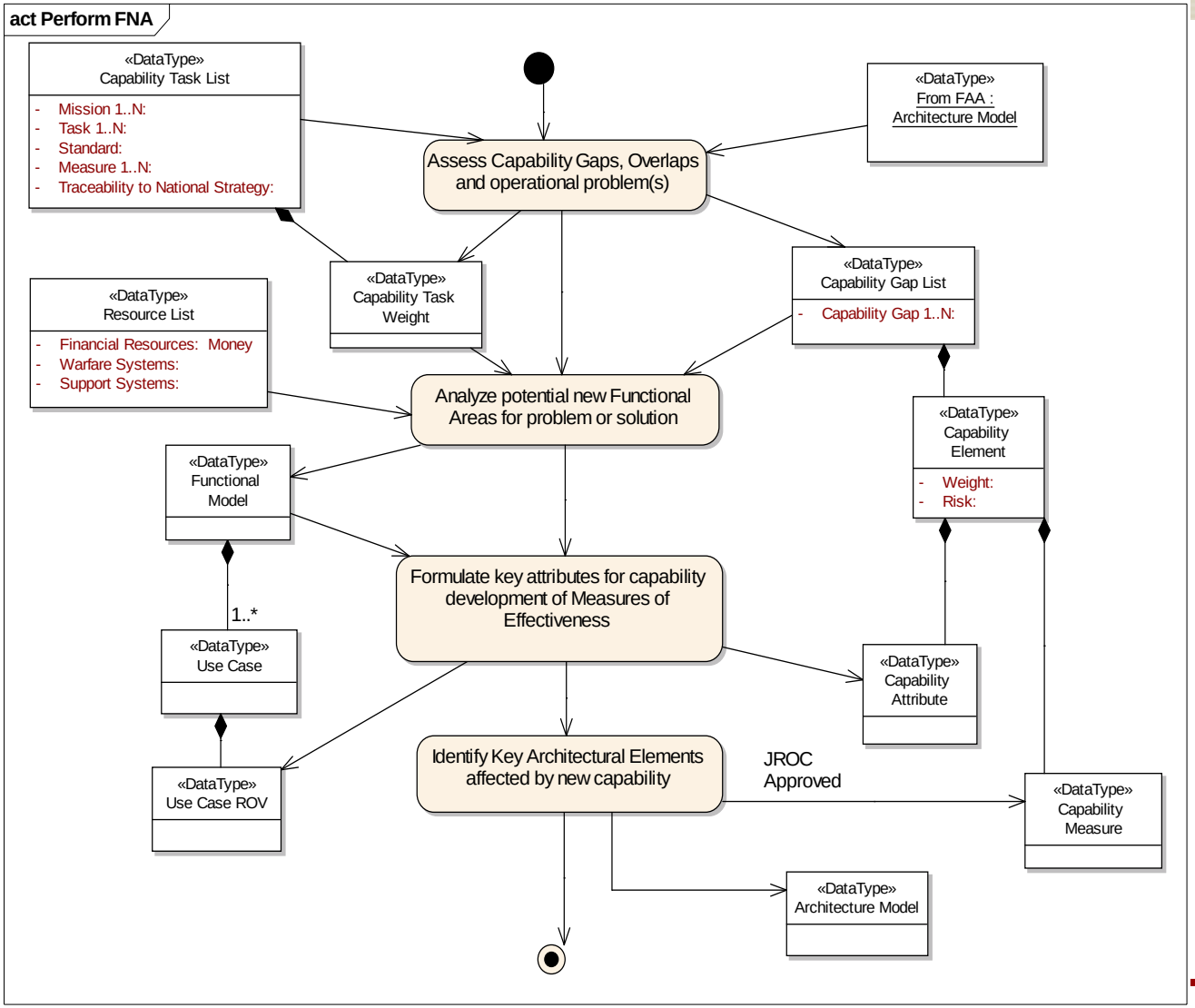
- Expand functional analysis from FAA
- Identify data elements/ data attributes
- Consider interface elements such as communications links
- Quantify measurable use case results of value
- Functional contributions of legacy systems and subsystems

Functional Analysis with Use Cases

- Use Case
  - Sequence of events that returns a measurable Result of Value (Booch, Rumbaugh, Jacobson)
  - Captures
    - Actors (Warriors performing the activities)
      - Roles, not specific individuals or commands
    - Activities (operations)
    - Data objects
      - Created and consumed by the activities
      - Information elements that are exchanged between the Operational Nodes
    - Any other relevant references such as UJTL tasks

Functional Analysis is basic to the Systems Engineering Method

FNA Activity Diagram



Example FNA Methodology

2. Select alternatives (screen based on FAA)

4. Scores less than one indicate capability gaps

FAA		Weight	Alternative A Score	Alternative B Score	Alternative C Score
Mission Type 1		0.30	0.79	0.79	0.69
Task 1.1	Standard 1.1.1	0.10	0.90	0.80	0.85
	Standard 1.1.2	0.05	0.85	0.90	0.60
Task 1.2	Standard 1.2	0.15	0.90	0.70	0.70
Task 1.3	Standard 1.3	0.30	0.80	0.80	0.80
Task 1.4	Standard 1.4	0.10	0.50	0.50	0.40
Task 1.5	Standard 1.5.1	0.05	0.70	0.70	0.50
	Standard 1.5.2	0.20	0.75	0.95	0.70
	Standard 1.5.3	0.05	0.95	0.90	0.50
Mission Type 2		0.30	0.90	0.70	0.80
Mission Type 3		0.30	0.80	0.90	0.70
Mission Type 4		0.10	0.70	0.90	0.60
Composite Score			**0.82**	**0.81**	**0.72**

1. Assign weights based on relative importance

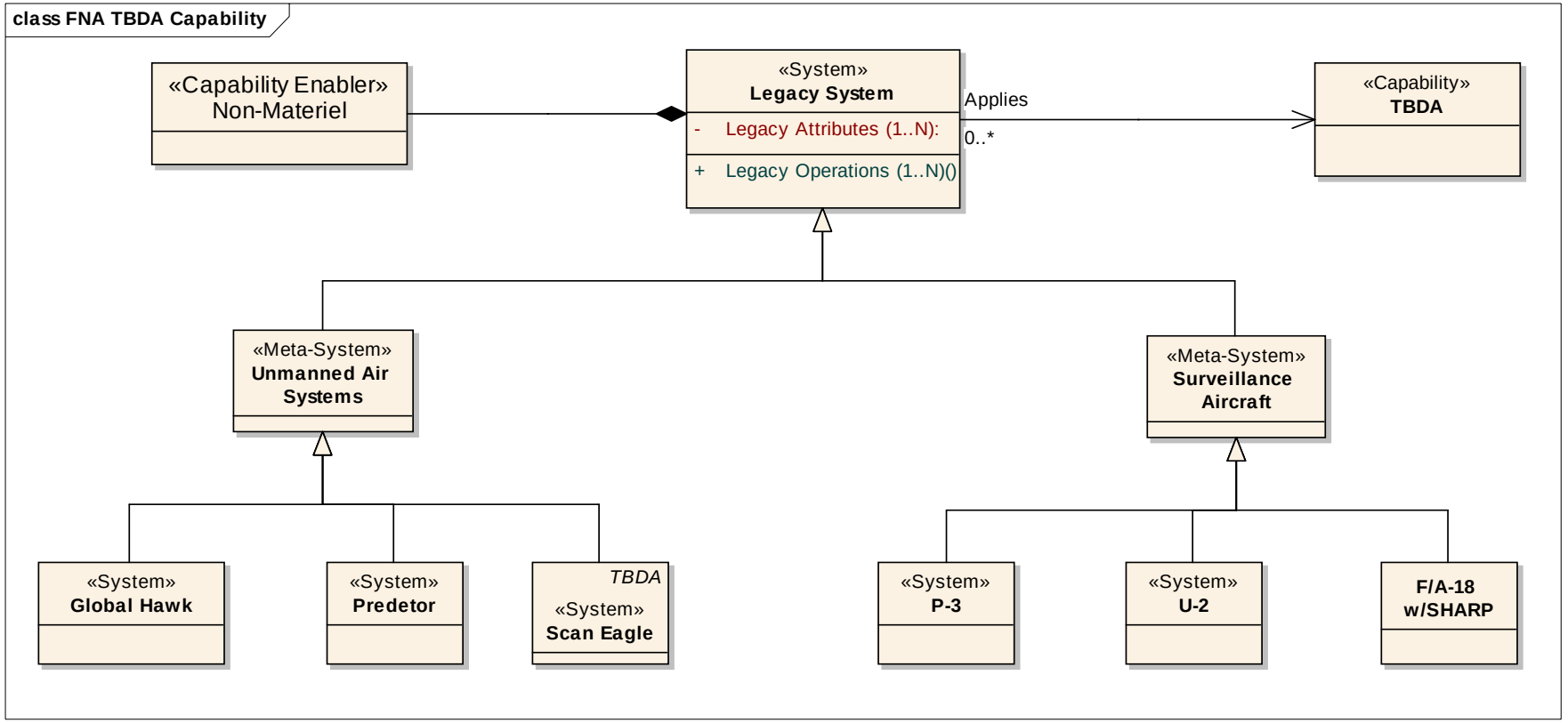
3. Evaluate performance of each alternative for each mission, task, and standard

FNA Artifacts

- Next iteration of Architecture Model including
  - Definition of Capability Elements
    - Model as Blocks including attributes, parameters and constraints
  - Definition of legacy systems that contribute to the capability
  - Capturing functional tasks as use cases with ROVs
  - Assignment of functional tasks to Capability (logical) Elements
  - Use cases assigned to Capability Elements as Block operations
- Capability measures forwarded to JROC for approval
- Requirements Traceability Matrix

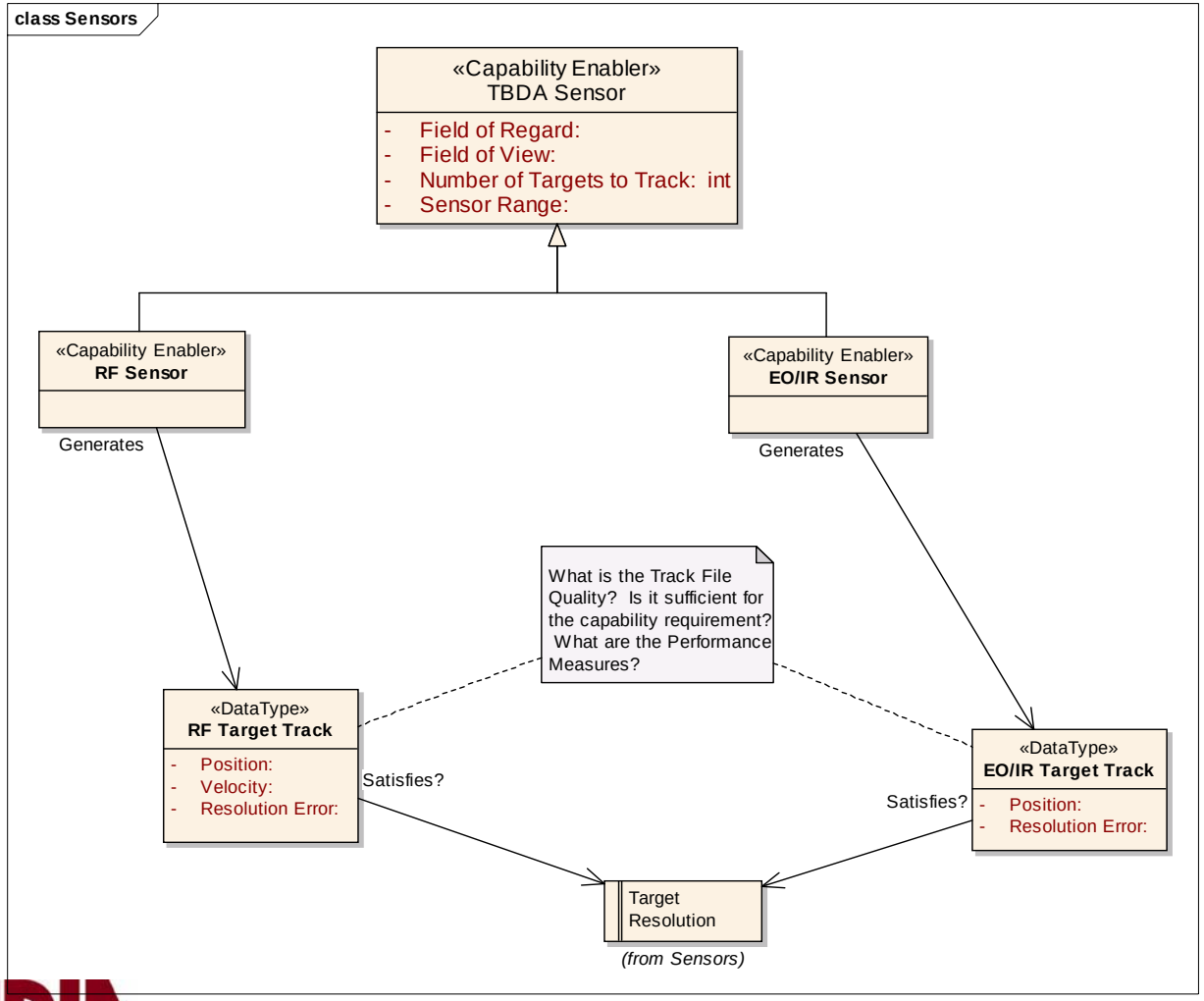
FNA for TBDA

Analysis of Legacy Warfare Systems



To what extent does the Legacy attributes and operations satisfy the capability need, including UJTL tasks?

FNA for Capability Enablers

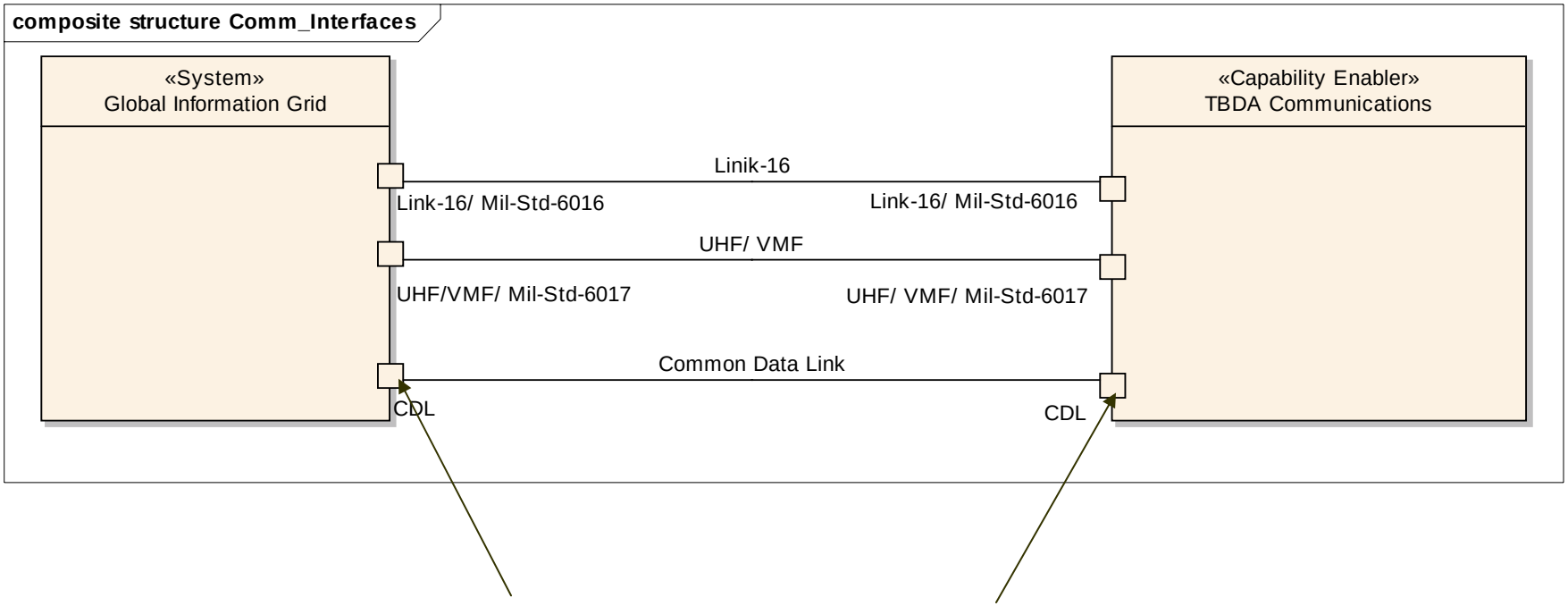


Existing subsystems/ components with **suitable performance measures** may provide some capability requirements, but will need to be integrated into an overall solution

Key Architectural Elements

- In the FNA, architectural elements are still abstractions (i.e. capability enablers) of real systems
- Architectures include behaviors, relationships AND rules for "rules governing their design over time" (DoDAF)
  - FNA is the time to consider the "possible" with regard to applications for the capability enablers
    - Including the standards that govern the application
- Example, TBDA Communications
  - Tactical application places limits on size, weight, range of operations
  - Logical conclusion (after analysis): Comm Applications limited to Link-16, UHF/ VMF and CDL
    - Standardized interfaces exist for those applications
    - Modeled using SysML Internal Block Diagram

TBDA FNA Communications Architecture

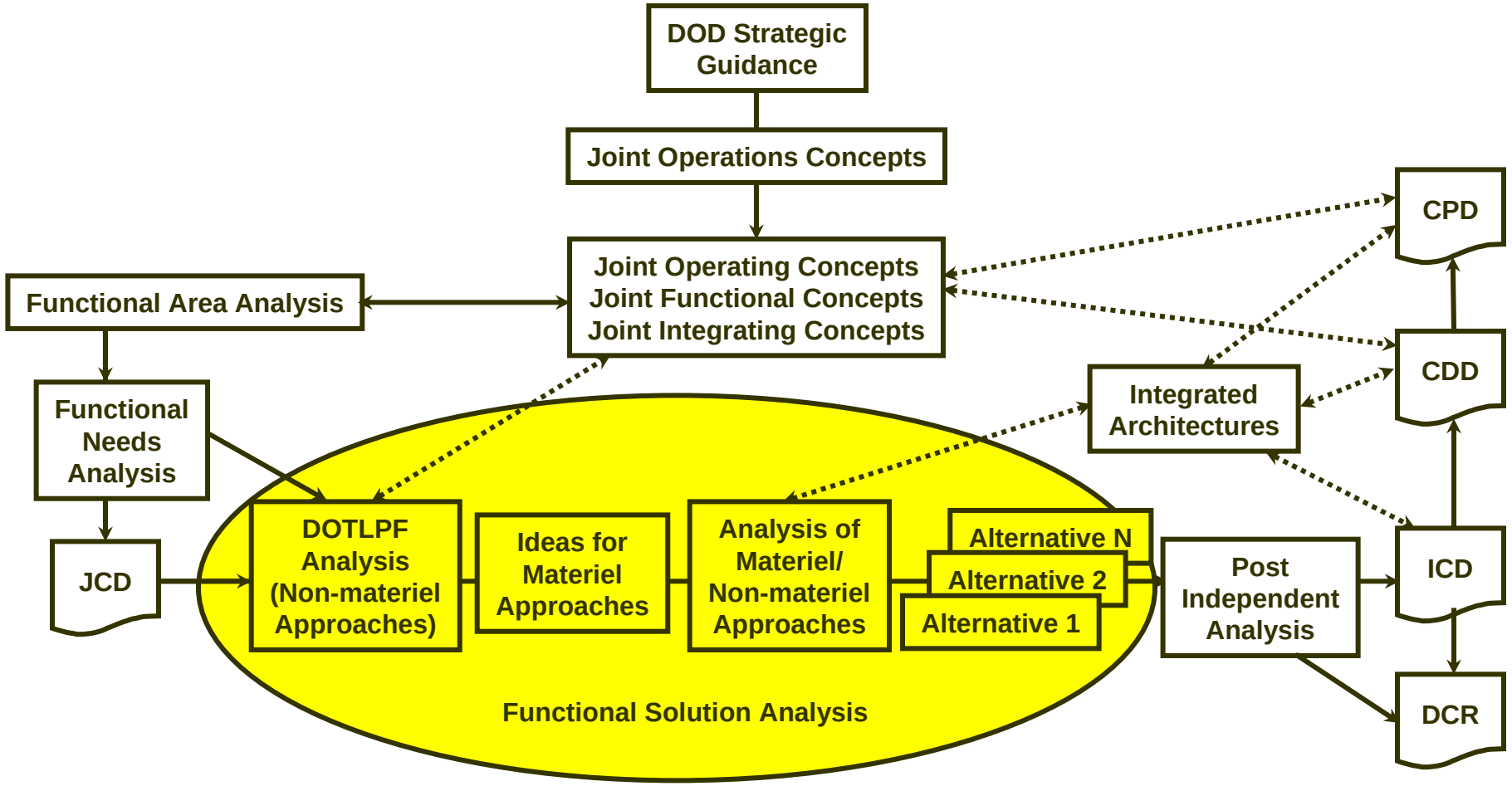


Port: Interface defined by Standard

TBDA FNA Model

- Define operational functionality and assign that functionality to the logical elements, i.e. Capability Enablers
- Define capability attributes with suitable measures of effectiveness
  - Assign measures to key architectural elements
- Do these elements satisfy the identified capability gaps?
  - If not, refine

JCIDS Process



**CJCSM 3170.01B*

Functional Solution Analysis (FSA)

- Operational assessment of all approaches to solving the capability gaps identified in the FNA
  - Non-materiel solutions
  - Materiel solutions (in priority order)
    - Product improvements to existing materiel or facilities
    - Adoption of interagency or foreign materiel solutions
    - Initiation of new materiel programs
- Basis for ICD

Transition from Problem Space to Solution Space

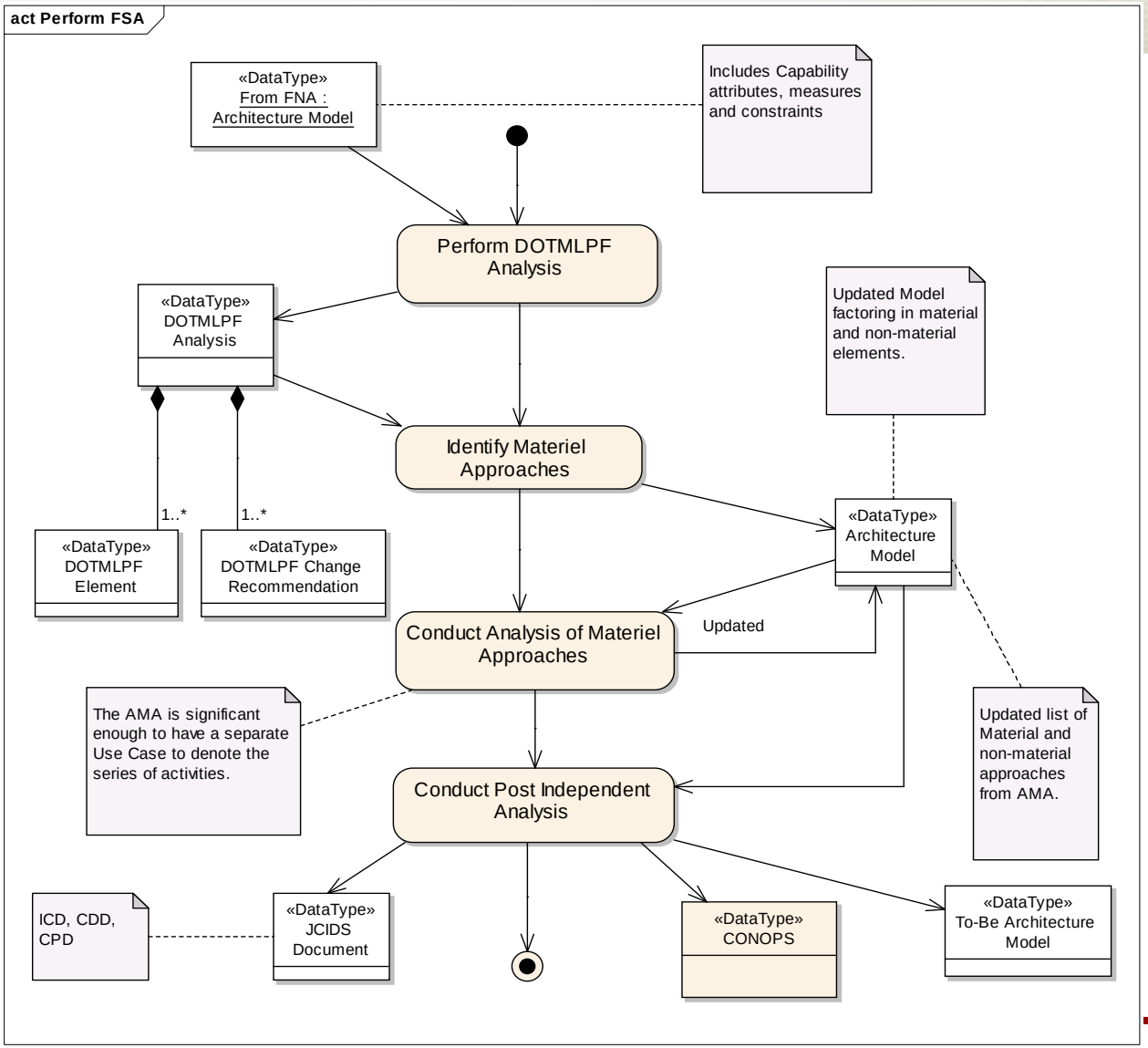
FSA Activities

- Define the Solution Space
  - Trace possible solutions to satisfactory “solve the problem”
- Conduct the DOTMLPF analysis
  - Model DOTMLPF Elements as Blocks that include attributes and operations
- Refine Use Cases and appropriate ROVs after DOTMLPF factored into Solution Space
- Analyze potential material solutions, i.e. Warfare Systems
  - Model Warfare Systems as logical elements and assign use cases – Assignment of functionality to physical elements

FSA Activities

- Analysis of Material Alternatives (AMA)
  - Analyze Capability Gap and range of military operations
  - Assess operational risk and DOTMLPF implications
  - Assess material impact to functional areas
- Program Independent Analysis (PIA)
  - Ensure the list of approaches with the potential to deliver the capability identified in the FAA and FNA is complete

FSA Activity Diagram

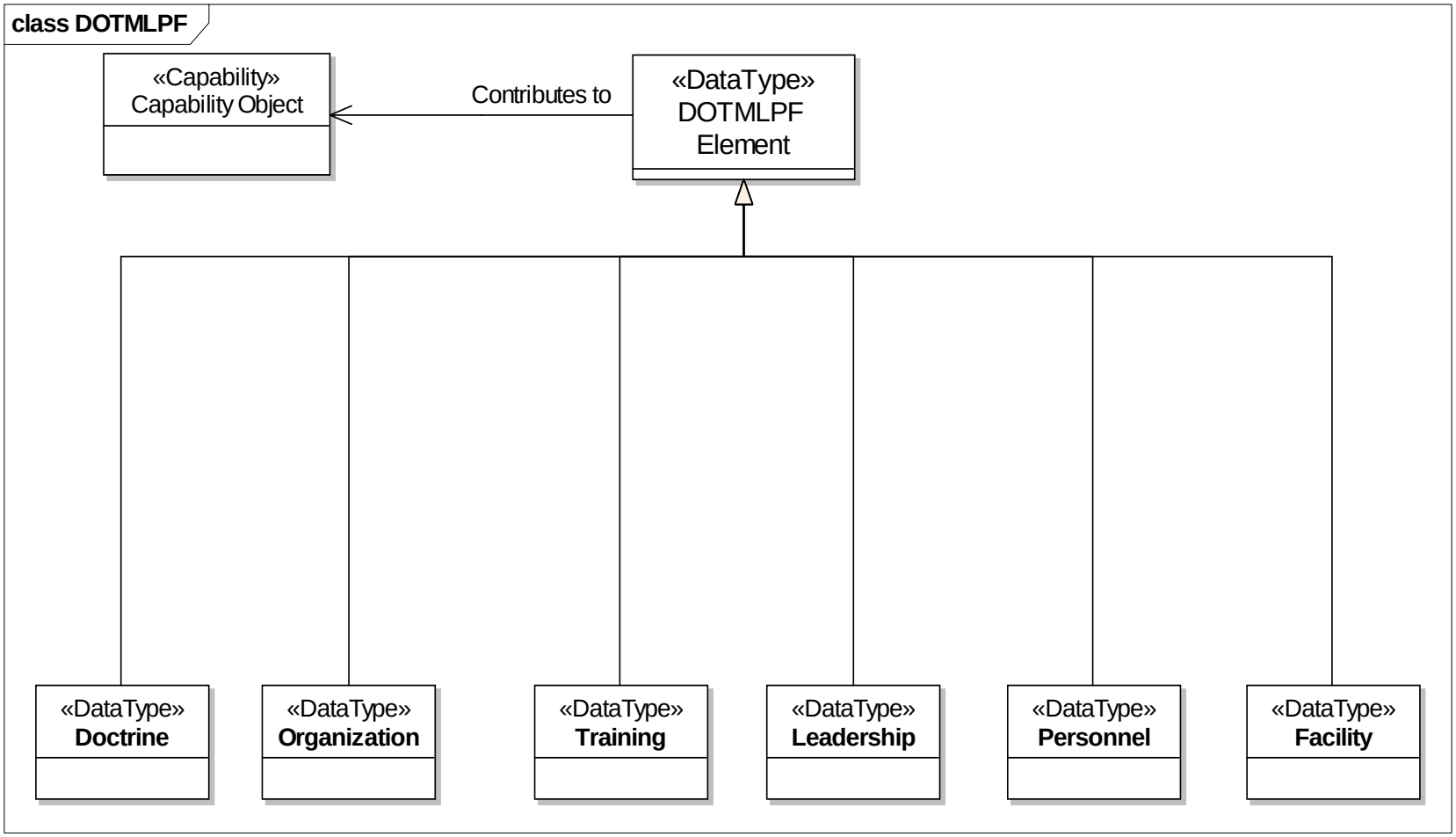


FSA: Non-Materiel Solutions

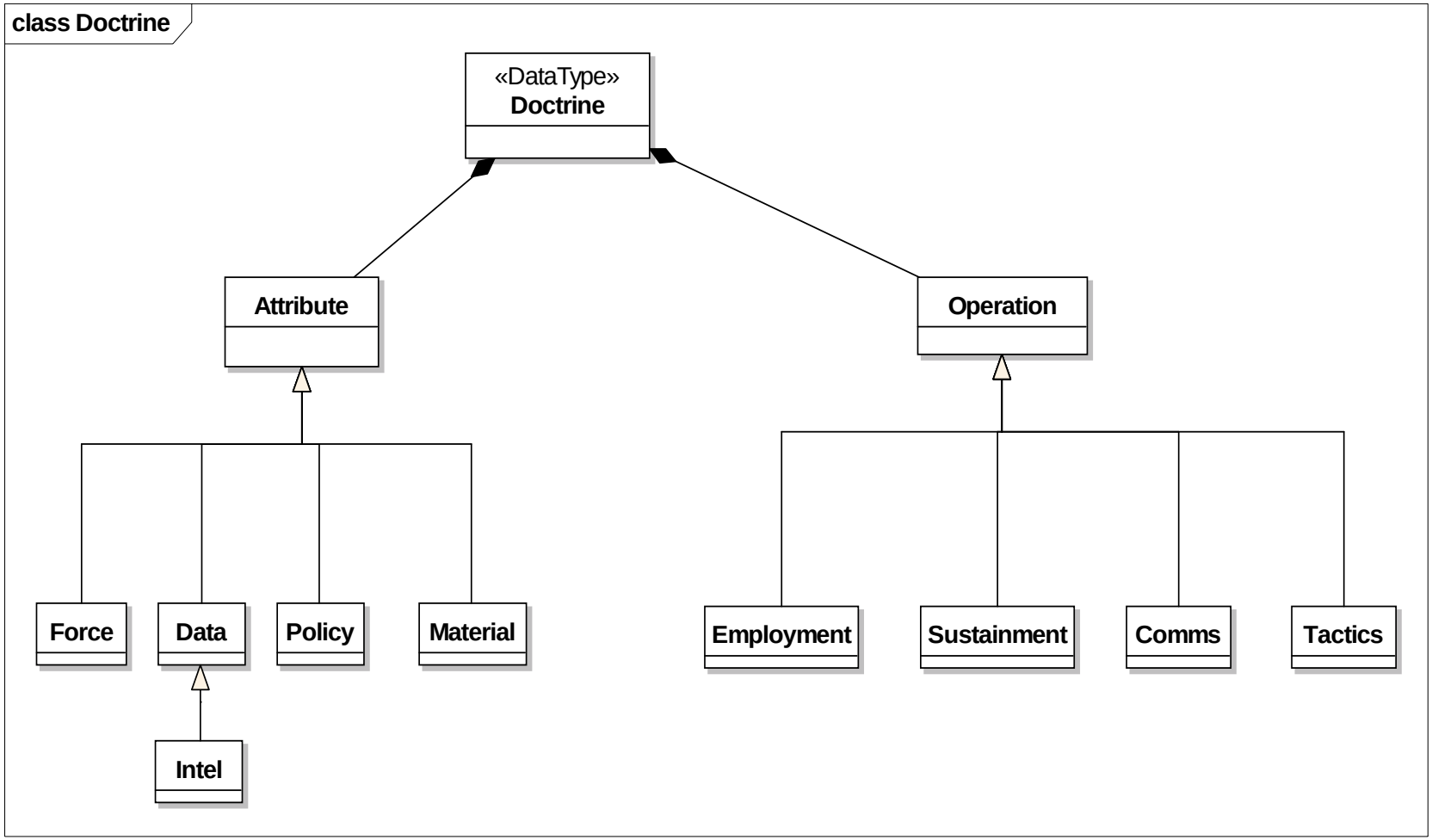
- **Can FNA capability gaps be mitigated via a non-materiel solution (DOT_LPF)**
  - **Doctrine**
  - **Organization**
  - **Training**
  - **Leadership/education**
  - **Personnel**
  - **Facilities**

Generally a qualitative assessment

DOTMLPF as a Logical Element



Doctrine “Block”



FSA: Materiel Solutions Analysis of Materiel Approaches (AMA)

- Assess potential materiel solutions to FNA capability gaps
  - Performance
  - Cost
  - Risk
- Some similarity to the Analysis of Alternatives (AoA)
  - Less rigorous
  - Less specific

Notional FSA Results

Approach	Effectiveness	Cost	Risk
A		$	
B		$$	
C		$	
D		$$$$	

Potential non-materiel and material approaches

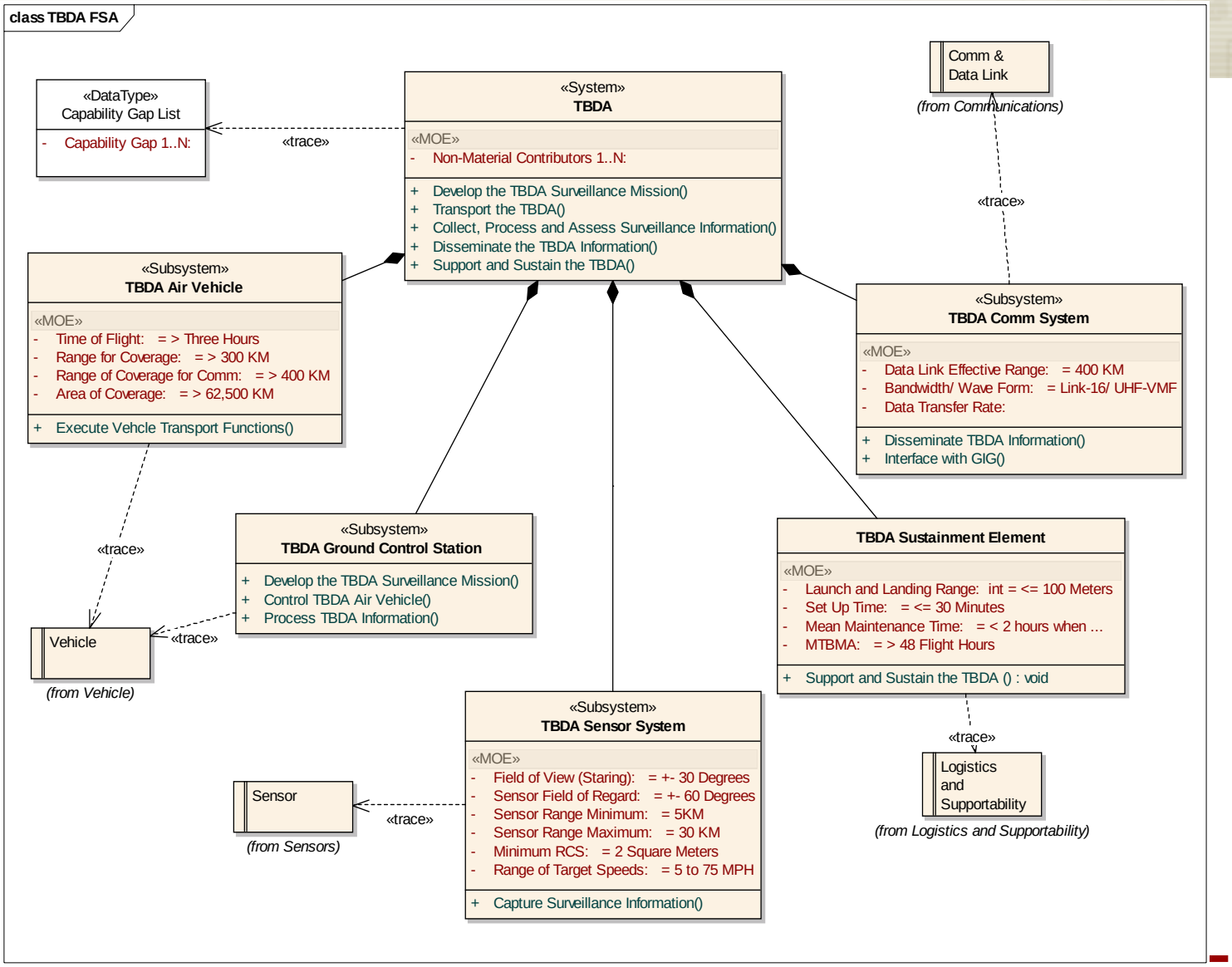
FSA Artifacts

- Final Architecture Model
  - "To-Be" model
  - Material elements that perform functional operations that provide capability
    - Measurable Results of Value
- JCIDS Document
  - ICD for Pre-Milestone A
  - CDD and CPD for every capability upgrade
- Concept of Operations (CONOPS)

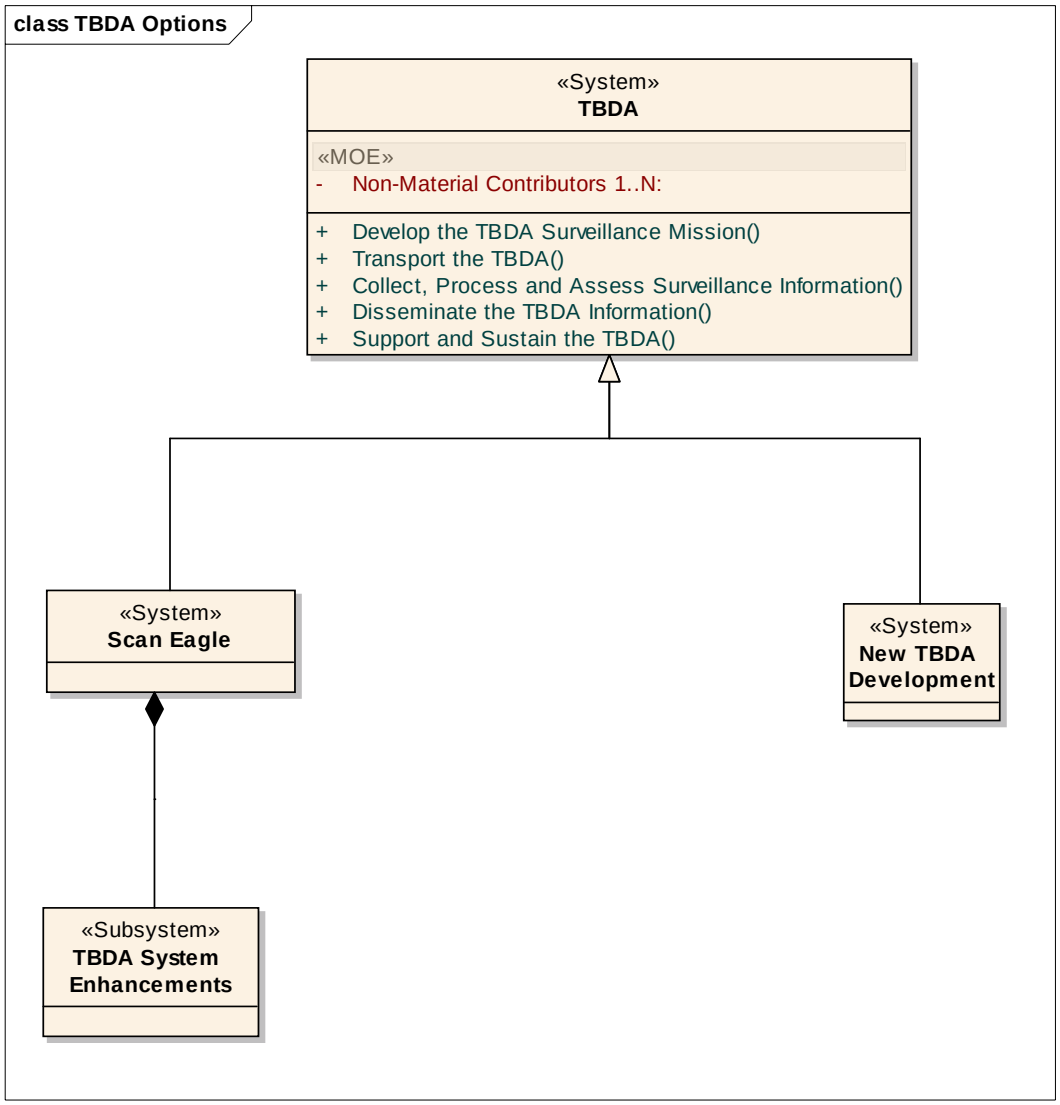
Concept of Operations Document

- The “CONOPS” is not a required JCIDS artifact, however
  - CONOPS document is a critical interface between the operational and the engineering communities
  - Provides potential developers the framework on how the capability will be applied in the operational environment
- Services may require some form of CONOPS
  - USAF Enabling Concept

FSA TBDA "To-Be" System

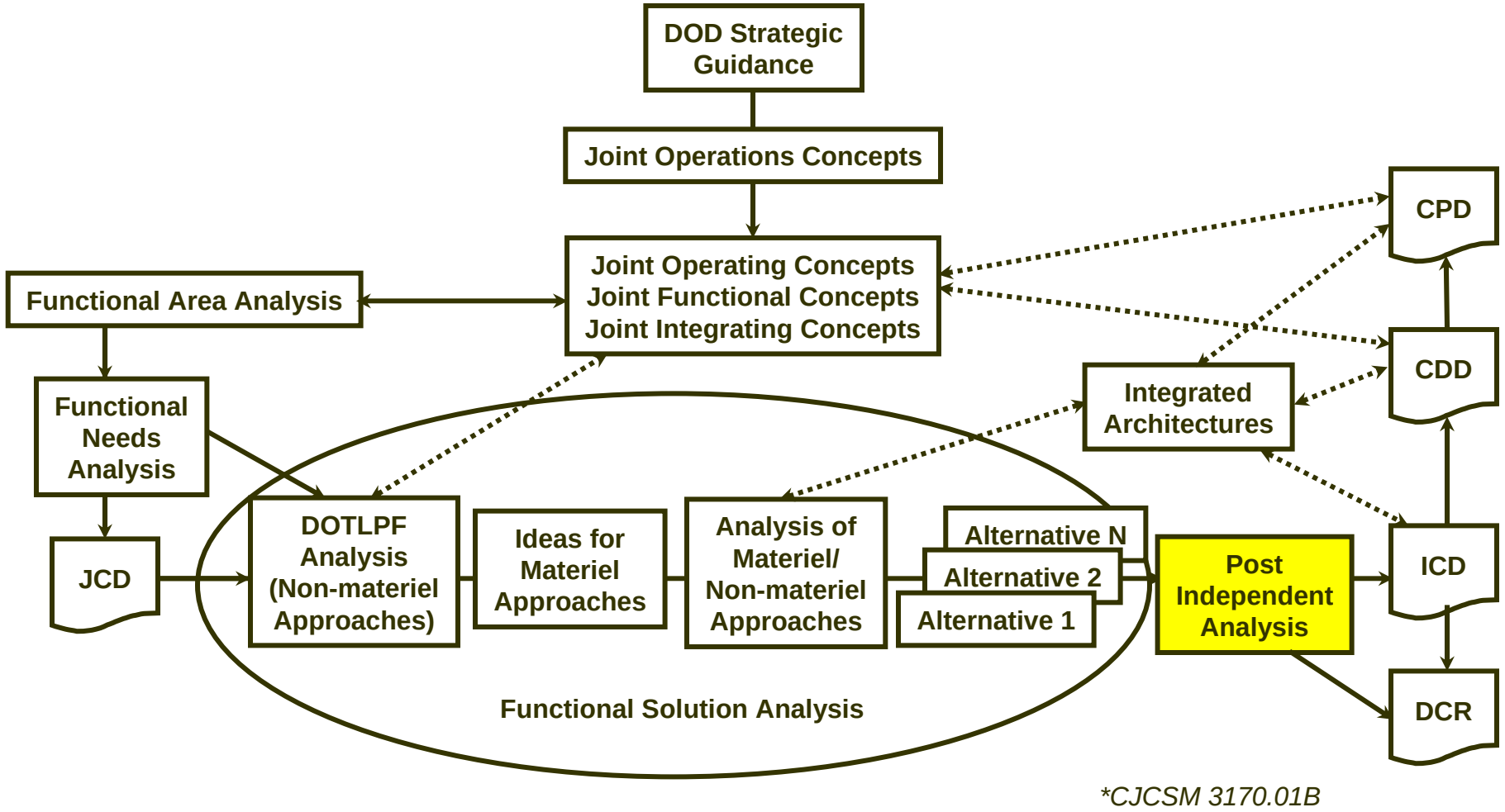


TBDA Development Options



Emphasis is still the Capability with options to pursue during concept evaluation and risk reduction phase (Post MS A)

JCIDS Process



**CJCSM 3170.01B*

Post Independent Analysis

- Final independent review of FAA, FNA, and FSA
  - Not the same people who conducted the analyses
  - Ensure…
    - Analyses were thorough
    - Potential solutions are reasonable
    - Potential solution set is complete

FAA, FNA, FSA, PIA Output

- There is no capability gap
- Capability gap can be addressed by change to:
  - DOT_LPF - Doctrine, organization, training, leadership/education, personnel, and facilities
  - DCR - DOTLPF Change Request
- A materiel solution is required
  - Initial Capabilities Document (ICD)

Conclusion on Functional Analyses

- FAA, FNA, FSA, and PIA are import steps to identify, assess, and prioritize joint military capability needs
  - FAA – required capabilities
  - FNA – gaps in planned capabilities
  - FSA – potential solutions
- Conducted through a combination of quantitative and qualitative analyses
- Involve all stakeholders in the process

Tutorial Wrap-up

- JCIDS is an engineering intensive process!
- The Systems Engineering Method is appropriate for guiding the JCIDS analyses in every phase of the capability/ system life cycle
  - Ensures traceability system functionality back to requirements
- Model Driven SE enables the JCIDS Team to fully understand what they are doing
  - SE Models provide the basis for the system's architecture and all architectural views
  - SE Model is a living entity that transitions from JCIDS Team to Development Team
    - Today's "To-Be" model becomes tomorrow's "As-Is"

Tutorial Wrap-up

- JCIDS Functional Analyses, including AMA and PIA, are essential SE functions
  - Each phase, from FAA through FSA, better quantifies the degree of "materialization"
    - Including non-materiel capability contributors
- OMG SysML is most appropriate for modeling capabilities from early conceptualization to system design
  - Either OO or Traditional Structured methods

Good SE ⟷ Effective JCIDS