Modeling System Life Cycle Concepts

Recommended approaches for modeling a complex, cyber-physical system's preliminary life cycle concepts during acquisition planning.

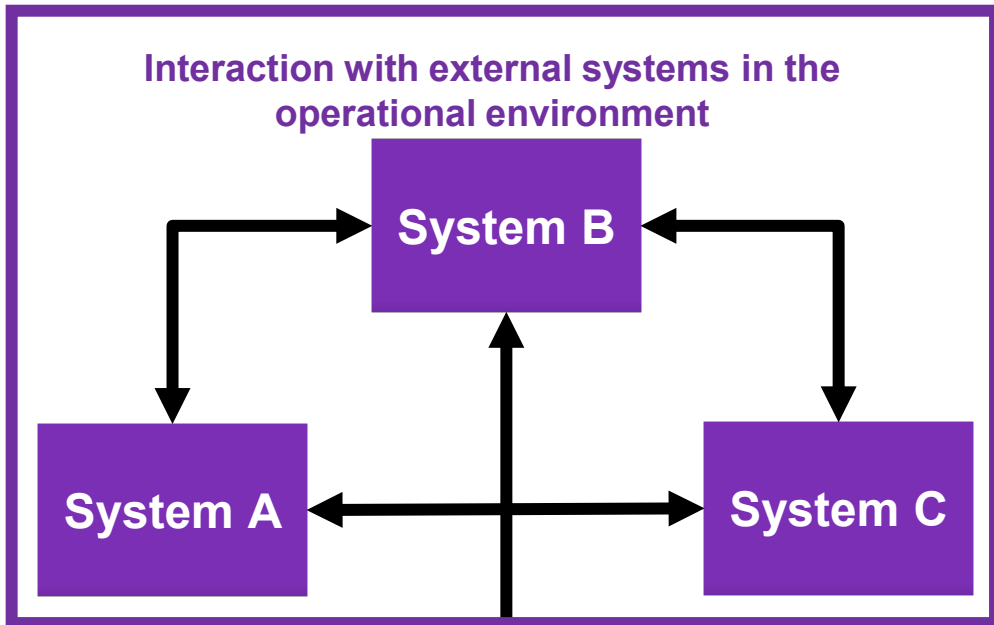NDIA 27th Annual Systems & Mission Engineering

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NOTE: This presentation assumes the audience has a fundamental understanding of:

- **Systems Engineering**, **Enterprise Architecture**, and **Mission Engineering** principles and practices;
- **Modeling** principles, practices, tools and languages in support of **Systems Engineering**, **Enterprise Architecture**, and **Mission Engineering**;
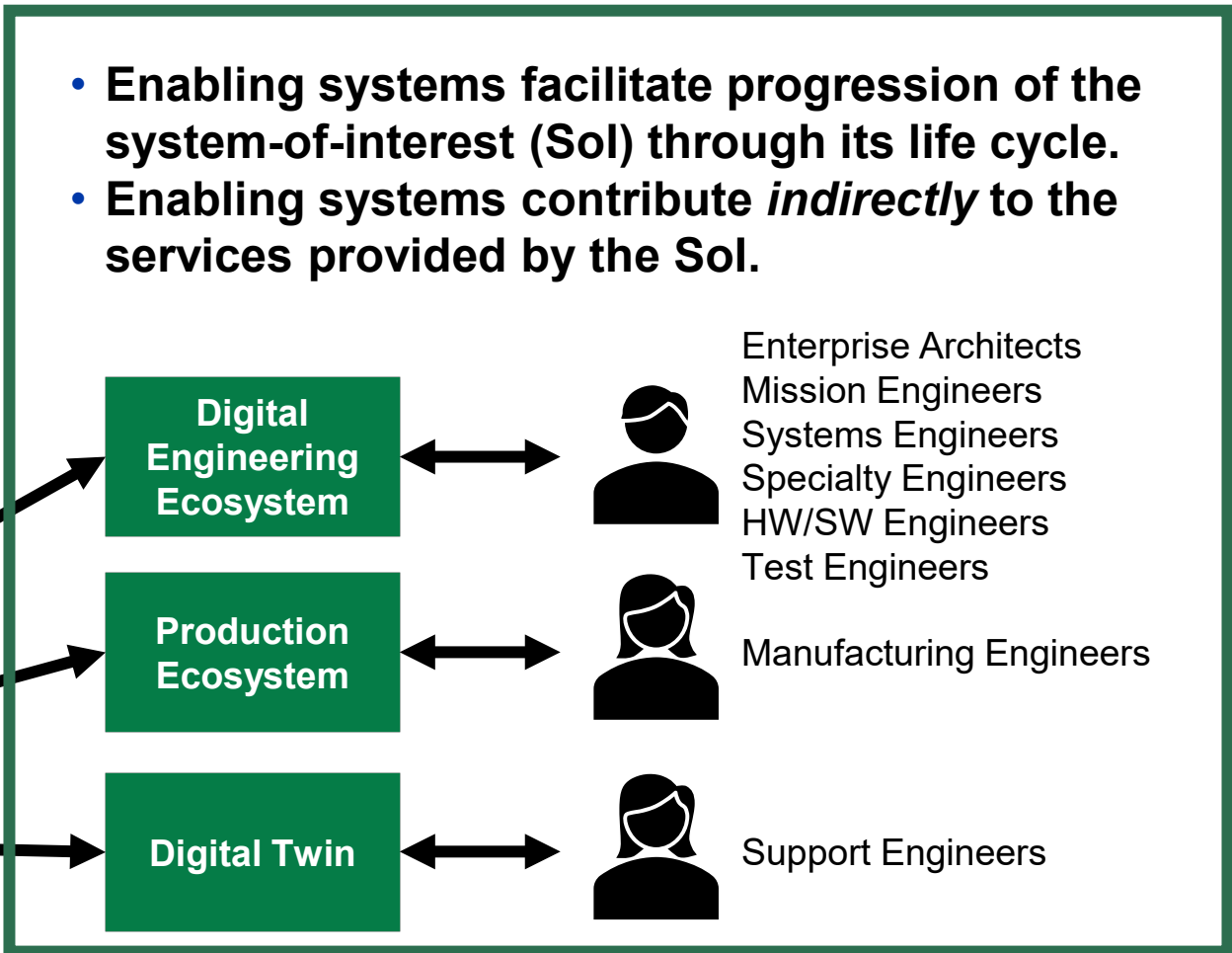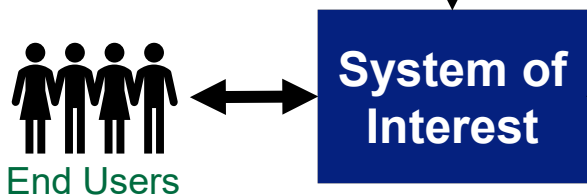- **Department of Defense (DoD)** acquisition processes.

What are Enabling Systems?

Interaction with external systems in the operational environment

System B

System A

System C

Reference: ISO/IEC/IEEE 15288:2023, Chapter 5.2.3

End Users

System of Interest

- **Enabling systems facilitate progression of the system-of-interest (SoI) through its life cycle.**
- **Enabling systems contribute *indirectly* to the services provided by the SoI.**

Digital Engineering Ecosystem → Enterprise Architects
Mission Engineers
Systems Engineers
Specialty Engineers
HW/SW Engineers
Test Engineers

Production Ecosystem → Manufacturing Engineers

Digital Twin → Support Engineers

During any stage in the system life cycle, the relevant enabling systems and the system-of-interest are considered *together*.

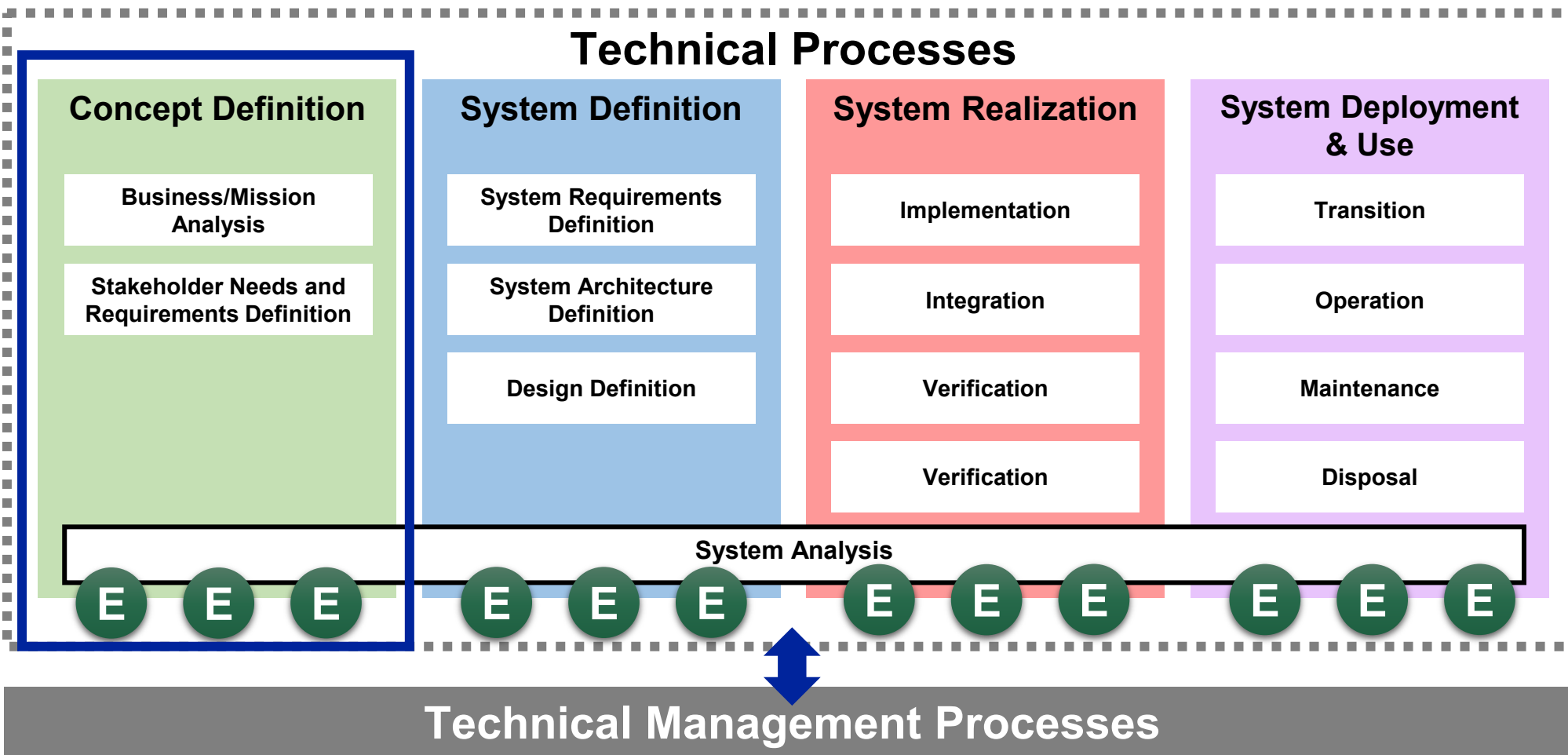# Generic Life Cycle Stages for a System of Interest

Reference: ISO/IEC/IEEE 24748-1:2024, Chapter 4.3.1

Definition

(E) Digital Engineering Ecosystem

Concept

Realization

Deployment & Use

NOTE: Some **enabling systems** may be more complex than the system of interest! (For example: Tesla's Manufacturing Ecosystem)

(E) Digital Engineering Ecosystem

(E) Manufacturing Ecosystem
Software Factory
Test Environment/Range

(E) Performance Monitoring System
Security Monitoring System
Training Environment
Digital Twin
Logistics Service
Recycling Service

(E) Enabling Systems

Enabling systems should be available for each life cycle stage of the system of interest to achieve the outcomes of the stage.

System Life Cycle Processes

Technical Processes

Concept Definition
- Business/Mission Analysis
- Stakeholder Needs and Requirements Definition

System Definition
- System Requirements Definition
- System Architecture Definition
- Design Definition

System Realization
- Implementation
- Integration
- Verification
- Verification

System Deployment & Use
- Transition
- Operation
- Maintenance
- Disposal

System Analysis

E E E   E E E   E E E   E E E

Technical Management Processes

Concept Definition and some System Definition may be performed as part of a Program Office's acquisition planning efforts.

Preliminary life cycle concepts—which includes the identification of enabling systems–are developed during the Concept stage.

Common Pitfalls of System Concept Definition

Failure to identify life cycle needs and the necessary enabling systems can result in significant program **schedule delays** and **cost overruns**, as well as **unintended consequences** on the environment.

Poorly-designed enabling systems can significantly decrease **program productivity**, **employee engagement**, **mission agility**, **mission effectiveness**, and much more.

"Oops! We didn't think through how we would retire the system and recycle its hardware components, so we don't have adequate funding for disposal. What can we do?"

"Our system architecture, design and implementation have drifted miles apart. What happened?"

"Our manufacturing facility can't produce the initial quantities of the system in time. We're going to have to delay the initial operational test & evaluation of the system."

"Hackers got into our training system and they may have stolen some of our employees' personal data."

A better *collective* understanding of a [enabling] system's life cycle concepts leads to better outcomes for all stakeholders!

Common Pitfalls of System Concept Definition

How can we achieve a better collective understanding of the **life cycle concepts** of a complex **cyber-physical system** and its **enabling systems and services** across all stakeholders?

Capturing all the data in **large documents**? Sure, but that's so 90s. ☺

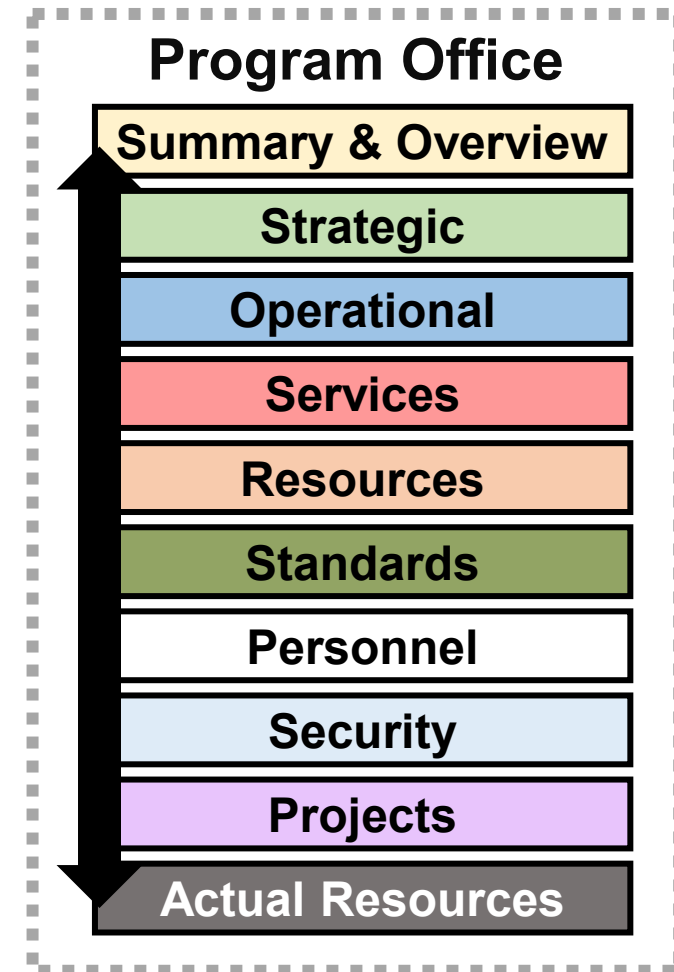Today, we utilize **DESCRIPTIVE MODELING**!

* Stock photo from Microsoft Office

Recommended Descriptive Modeling Approaches for System Life Cycle Concepts

Recommended Modeling Approaches for System Life Cycle Concepts

A potential **system of interest** and its **preliminary life cycle concepts** are initially defined as part of the Business/Mission Analysis process.
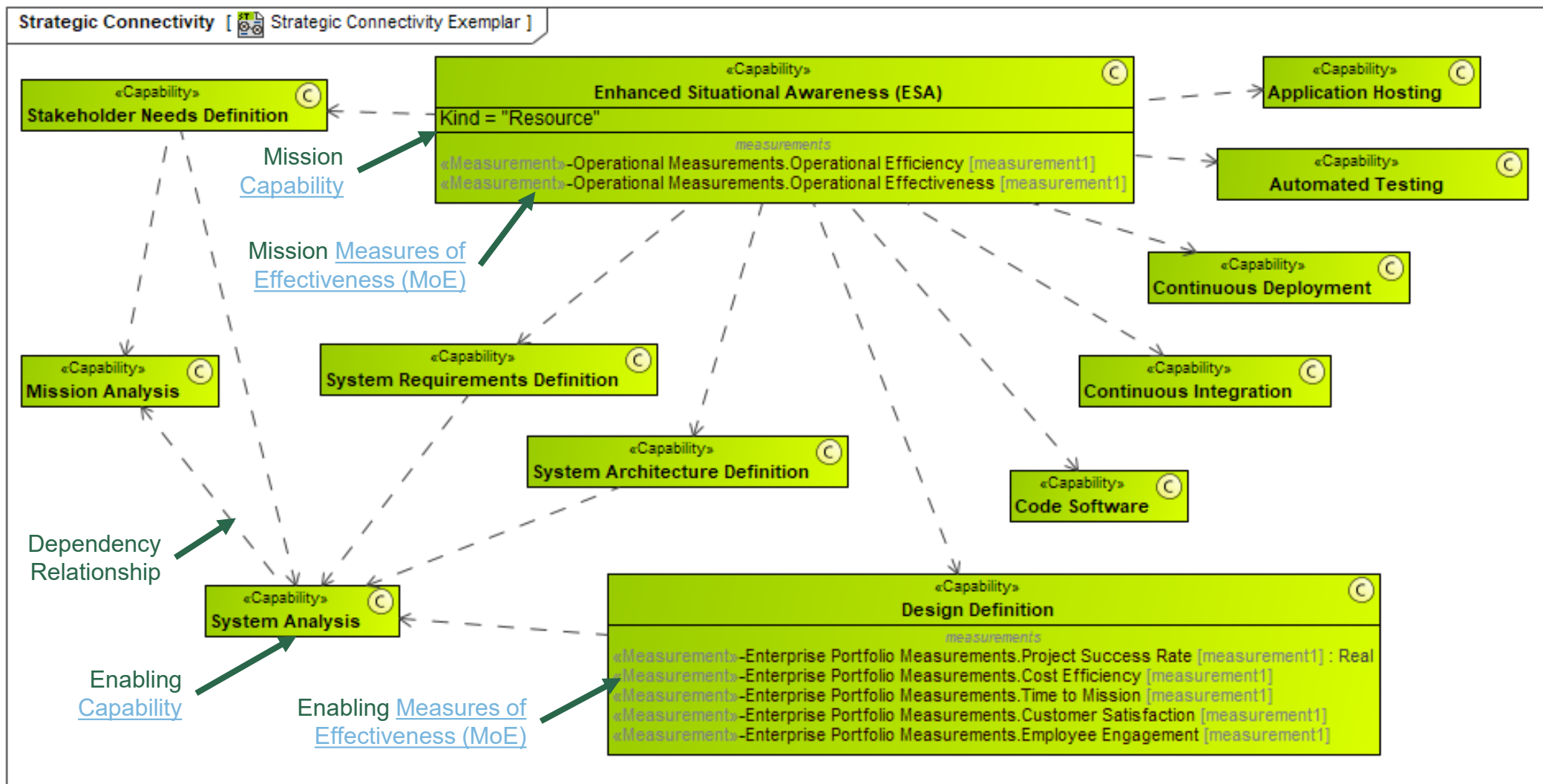
NOTE: Business/Mission Analysis is typically performed as part of the DoD Adaptive Acquisition Framework (i.e., pre-acquisition activities).

Recommendation #1: Utilize the Enterprise Architecture (EA) Guide for Unified Architecture Framework (UAF), Version 1.2 to support Business/Mission Analysis and describe a potential system's **preliminary life cycle concepts** using the UAF Modeling Language (UAFML).

Program Office

- Summary & Overview
- Strategic
- Operational
- Services
- Resources
- Standards
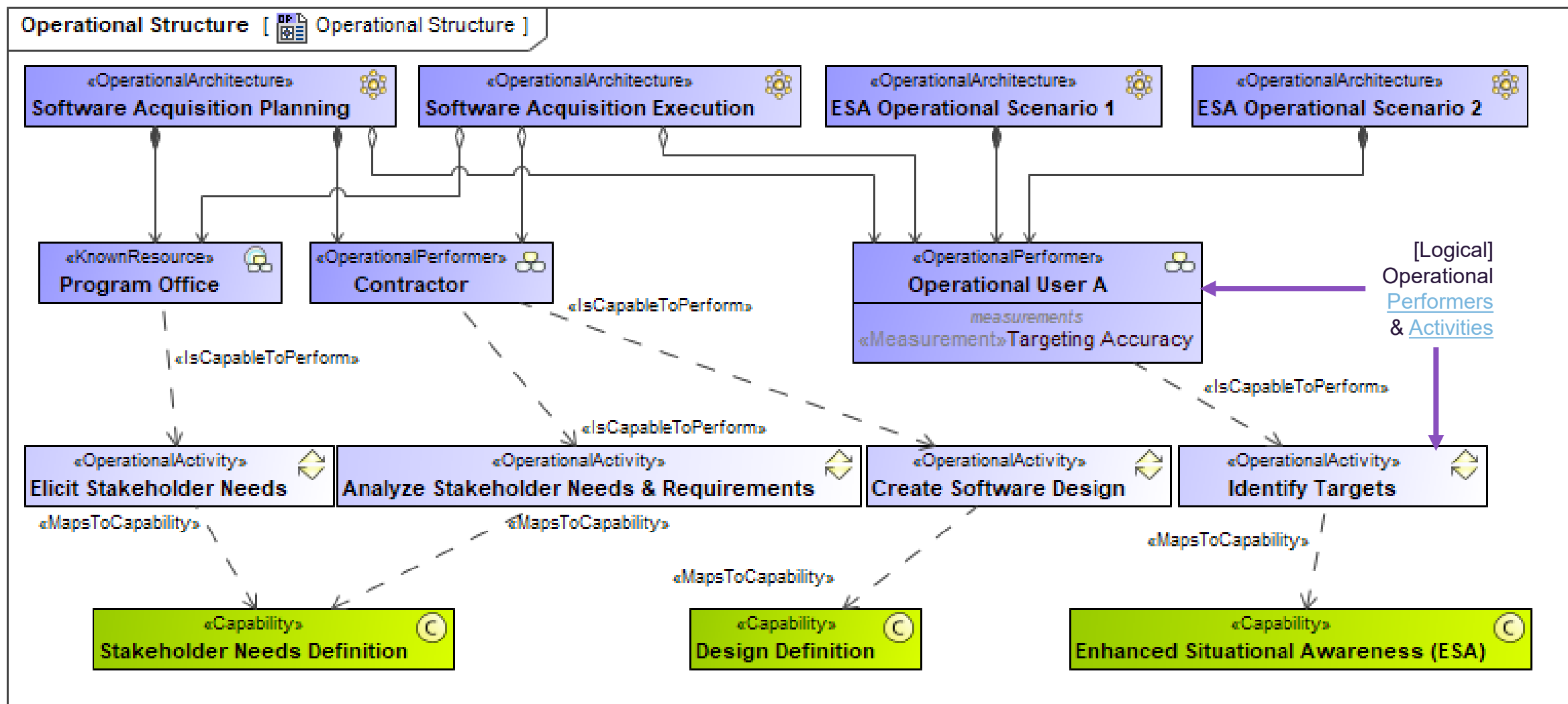- Personnel
- Security
- Projects
- Actual Resources

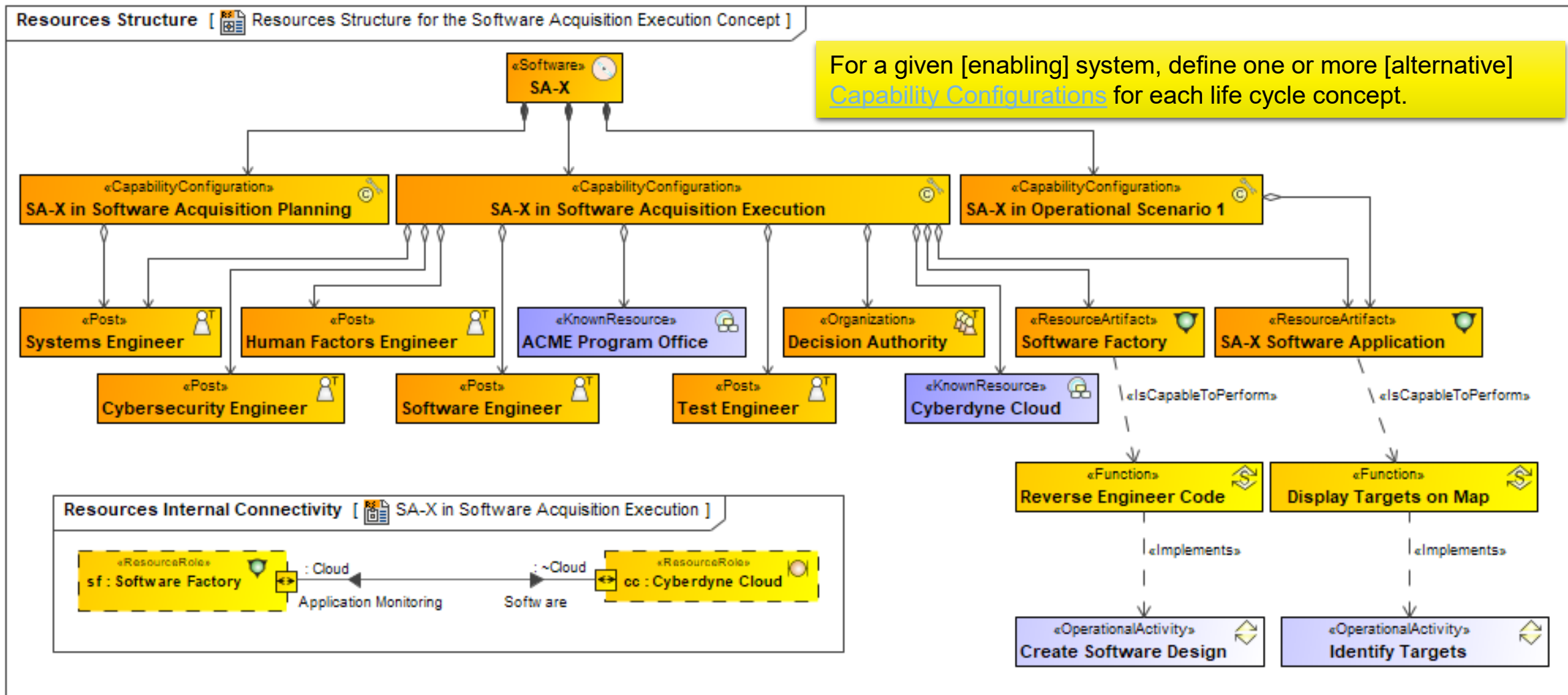# Define strategic mission and enabling Capabilities

EA Guide for UAF v1.2, Steps 2.2 & 2.3

Define a CONOPS that realizes the strategic Capabilities

EA Guide for UAF v1.2, Step 3.0

Evaluate Resource alternatives that implement the CONOPS

For a given [enabling] system, define one or more [alternative] Capability Configurations for each life cycle concept.

EA Guide for UAF v1.2, Steps 4.0, 5.0 & 6.0

Recommended Modeling Approaches for System Life Cycle Concepts

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MagicGrid Standard			Pillar				
			Requirements	Structure	Behavior	Parameters	Safety & Reliability
Domain	Problem	Black Box	Stakeholder Needs	System Context	Use Cases	Measures of Effectiveness (MoE)	Conceptual and Functional Failure Mode & Effects Analysis (FMEA)
		White Box		Conceptual Subsystems	Functional Analysis	MoEs for Subsystems	Conceptual Subsystems FMEA
	Solution		System Requirements	System Structure	System Behavior	System Parameters	System Safety & Reliability (S&R)
			Subsystem Requirements	Subsystem Structure	Subsystem Behavior	Subsystem Parameters	Subsystem S&R
				System Configuration Structure	System Configuration Behavior	System Configuration Parameters	System Configuration S&R
	Implementation		Implementation Requirements				

The [enabling] system's **preliminary life cycle concepts** are further refined and elaborated as part of the Stakeholder Needs and Requirements Definition process.

NOTE: Stakeholder Needs and Requirements Definition is typically performed as part of the DoD Adaptive Acquisition Framework (i.e., pre-acquisition activities).

Recommendation #2: Utilize the MagicGrid Book of Knowledge, 2nd Edition to support Stakeholder Needs and Requirements Definition and refine & elaborate the [enabling] system's preliminary life cycle concepts identified during Business/Mission Analysis using the Systems Modeling Language (SysML). (Chapter **Problem domain**)

Recommended Modeling Approaches for System Life Cycle Concepts

TIP: Although you can utilize SysML inside of UAFML projects, it is suggested that you keep your UAFML and SysML projects separate and distinct.

- Utilize UAFML projects for enterprise, business and/or mission modeling
- Utilize SysML projects for modeling individual systems, products, services and product lines

TIP: Utilize additional UAFML projects for creating traceability relationships between system model elements in SysML projects and enterprise model elements in UAFML projects.

- Prevents SysML projects from being automatically converted to UAFML!

TIP: When using MagicGrid, the government typically "owns" the *Problem Domain* and the *System Requirements* model elements throughout the acquisition life cycle

- The prime contractor and their subcontractors own the rest of the *Solution Domain* and *Implementation Domain* model elements

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Define System Contexts based on Capability Configurations
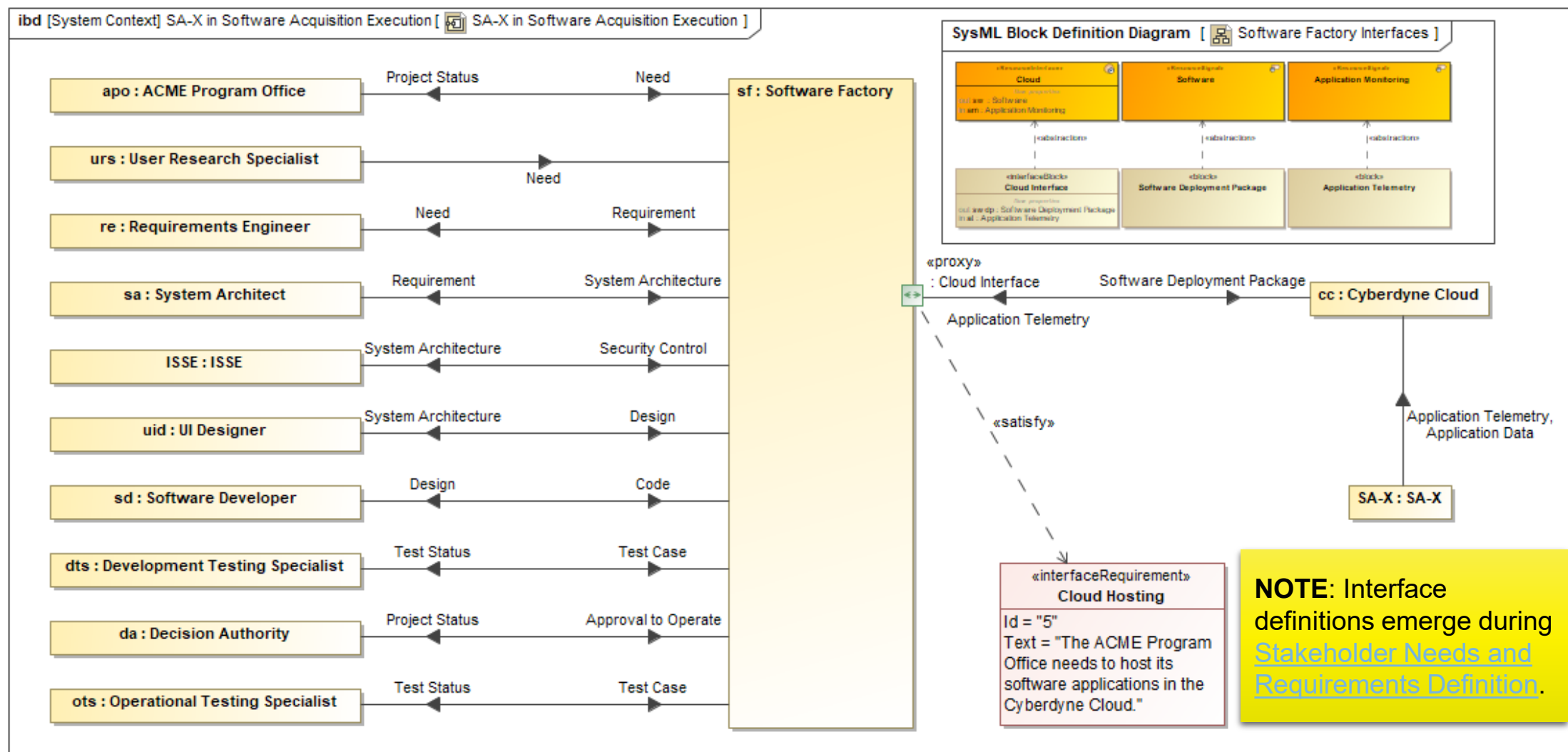
MagicGrid, Chapter *System Context*

Trace System Contexts to Capability Configurations

	SA-X in Software Acquisition Execution	cc : Cyberdyne Cloud	cse : Cybersecurity Engineer	da : Decision Authority	hfe : Human Factors Engineer	peo : ACME Program Office	sa-x app : SA-X Software Application	se : Systems Engineer	sf : Software Factory	swe : Software Engineer	te : Test Engineer
SA-X	1	1	1	1	2	1	1	2	1	1	2
SA-X in Software Acquisition Execution	↗										
apo : ACME Program Office						↗					
cc : Cyberdyne Cloud		↗									
da : Decision Authority				↗							
dts : Development Testing Specialist											↗
ISSE : ISSE			↗								
ots : Operational Testing Specialist											↗
re : Requirements Engineer								↗			
sa : System Architect								↗			
SA-X : SA-X							↗				
sd : Software Developer										↗	
sf : Software Factory									↗		
uid : UI Designer					↗						
urs : User Research Specialist					↗						

TIP: Optional SysML *Rationale* elements can be associated with specific traceability relationships for justification and clarifications purposes.

NOTE: Gaps in traceability matrices may expose misunderstandings within the Program Office.

MagicGrid, Annex B: *From System of Systems to System Architecture*

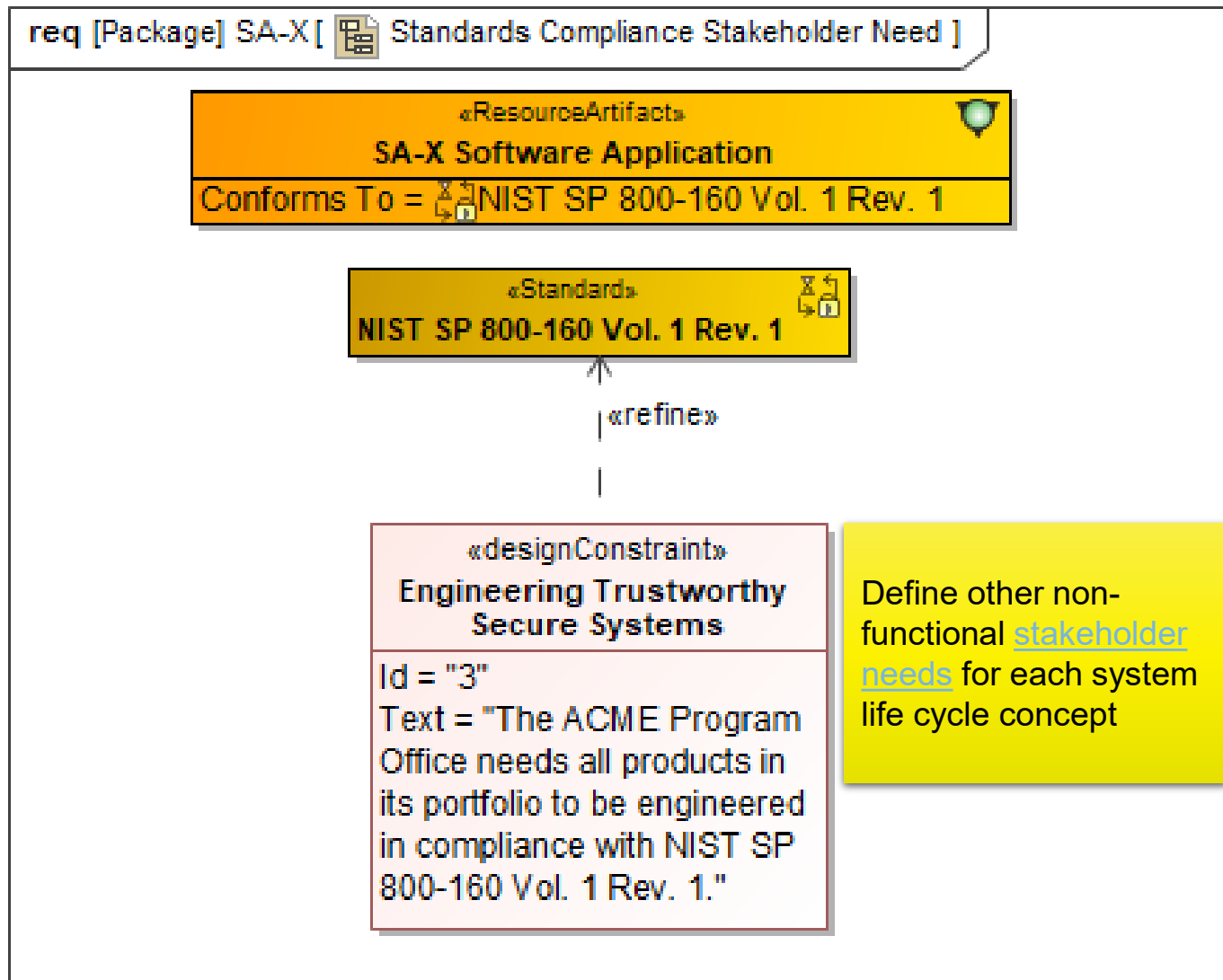# Derive and trace Stakeholder Needs, Use Cases, and MoEs
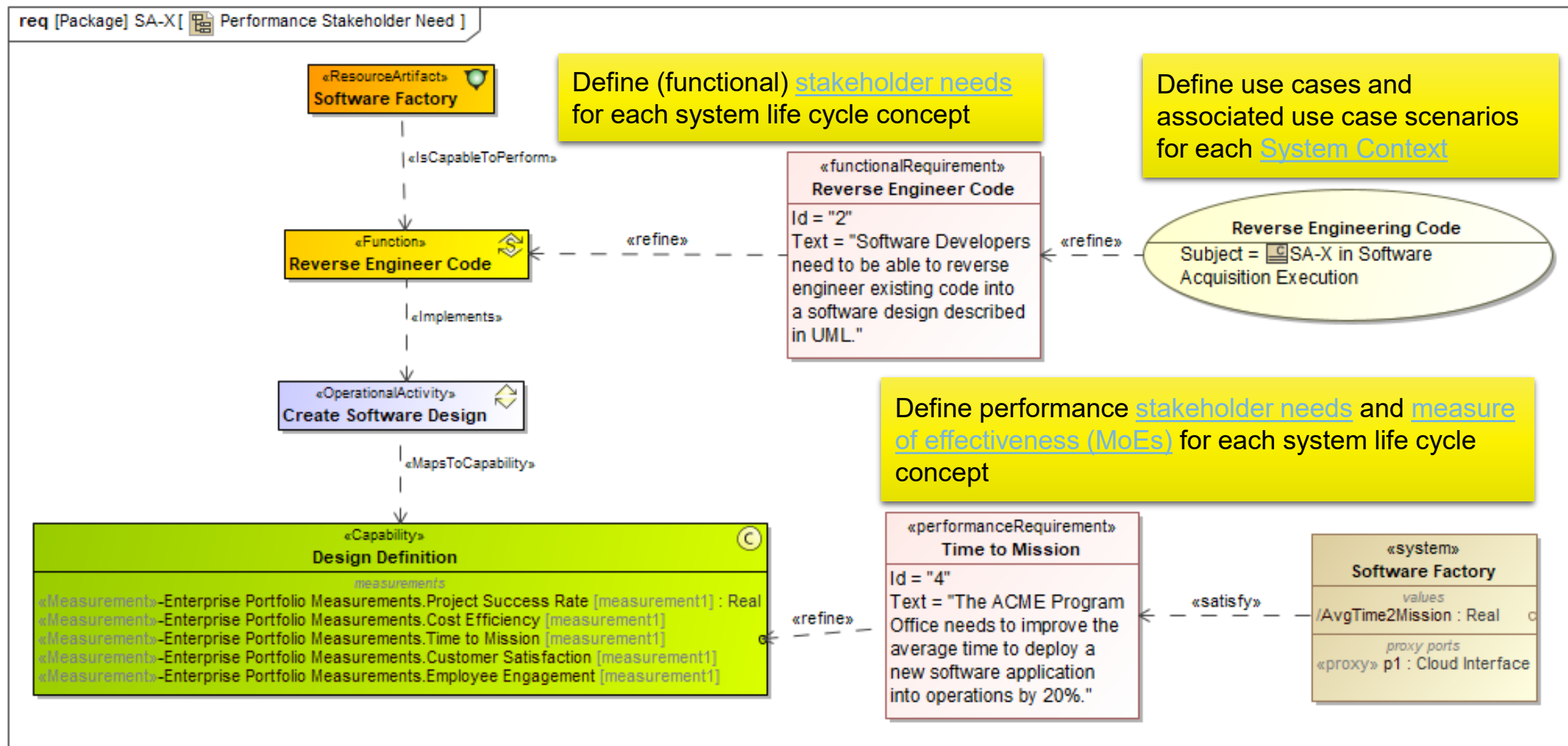
MagicGrid, Chapters *Stakeholder Needs*, *Use Cases*, *Measures of Effectiveness*, & Annex B: *From System of Systems to System Architecture*

Derive and trace Stakeholder Needs, Use Cases, and MoEs

Recommended Modeling Approaches for System Life Cycle Concepts

Now we have a consolidated and integrated set of stakeholder needs for the cyber-physical system's operational concept AND **other life cycle concepts**—fully described in one or more **(integrated) UAFML** and/or **SysML models**.

Program Offices can use these models to better estimate **life cycle costs** for the cyber-physical system during **acquisition planning**.

Defense contractors and Program Offices continue to **evolve** these models of the life cycle concepts during the **acquisition program** → **design better [enabling] systems** that meet the needs of ALL stakeholders.

In Summary

A better, collective understanding of a [enabling] system's life cycle concepts leads to **better acquisitions** with **better outcomes** for all stakeholders…

…and descriptive modeling using UAFML and SysML can **improve all stakeholders' understanding** of a [enabling] system's life cycle concepts!