Domain Modeling

Roadmap to Convergence

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"You got to be careful if you don't know where you're going, because you might not get there."

- Yogi Berra

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Overview

- Introduction
- Conceptual Modeling Process Overview
- Domain Modeling as the Foundation of the Conceptual Model
- Domain Modeling Application Across the Project
  - Analysis
  - M&S, Software Engineering
  - Systems Engineering / Architecting
  - Business Processes
- Domain Modeling “Goods and Others”

Why are we here?

- Initial activities on a modeling and simulation (M&S) project for a large, complex, integrated system attempted:
  - To develop generic DoDAF artifacts,
  - To link these artifacts more closely to developed models,
  - To provide a basis for new M&S development across a wide community of stakeholders.
- Issues
  - Legacy tool challenges for complex systems-of-systems analysis (configuration/preparation time, fidelity, and interoperability).
  - Lack of standardized foundation.
  - Traditional architectures often difficult to assess using M&S (lacked underlying referential structure).
  - Activities difficult to accurately plan and estimate.

How can we fix it?

Introduction

Problem Domain:

The real-world things and concepts related to the problem that the system is being designed to solve.

Domain Modeling:

The task of discovering "objects" (classes) representing things and concepts, and the relationships between them.

[Rosenberg and Scott 2001]

Problem Statement:

Develop efficient techniques to support complex system analysis

Given:

Complex systems, lots of components, subsystems, sophisticated behaviors, networks, information processing, collaboration

Organizations involved in design & development of these systems

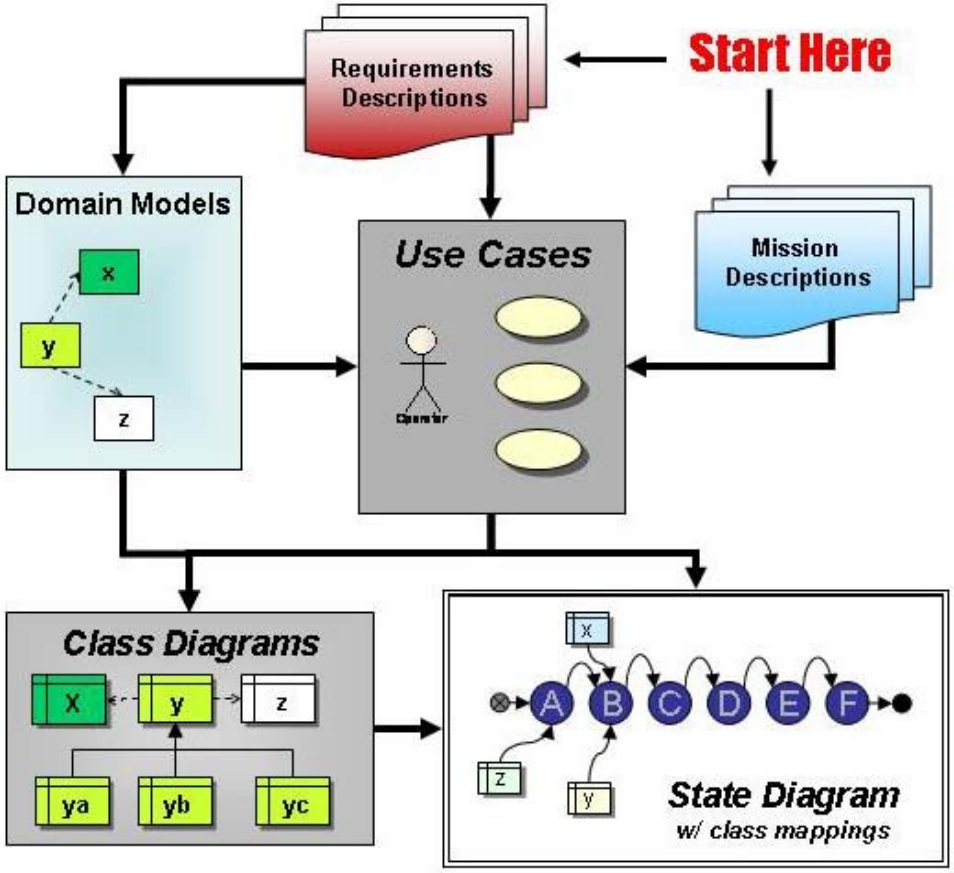
Analysis, requirements, architecture, systems engineering, software engineering, testing, operations.

Approach:

*Understand the problem **Domain** and progress from there…*

Conceptual Modeling Process

- Based on standard software and systems engineering processes.*
- Translates informal, generalized information from disparate sources into formal system models.
- Maintains focus on understanding and standardizing the problem space before moving on to the solution.
- Allows iteration and feedback until it's "right."
- Produces documentation allowing traceability throughout the process.



* Though significantly changed, this conceptual modeling process is informed by ICONIX, a software engineering process falling between RUP and XP with respect to rigor and flexibility. ICONIX is documented in Rosenberg and Stephens [2007].

Conceptual Modeling Importance

"Conceptual modeling is almost certainly the most important aspect of the simulation modeling process . . . . A well-designed model significantly enhances the possibility that a simulation will meet its objectives within the required time-scale. What sets truly successful modelers apart is their effectiveness in conceptual modeling."

[Robinson 2004]

The first, crucial step in conceptual modeling is ***Domain Modeling.***

Domain Model

What it is: **A "10,000-foot view," a live "project glossary," a simplified class diagram.**

How to do it:

- **Create list of candidate domain entities by extracting nouns from input documents.**
- **Review list, standardizing and defining terms.**
- **Deploy entities in a simplified class diagram (no attributes or operations) and draw important relationships (generalization, composition/aggregation).**
- ***Iterate as needed with all stakeholder groups and revisit throughout the project.***

What it is for:

- **Answers the question, "What makes up the system and its environment?"**
- **Defines the scope of the project, standardizes terms.**
- ***Provides foundation for static structural model.***

Domain Model Input

What it is: **Known information about the system and its environment.**

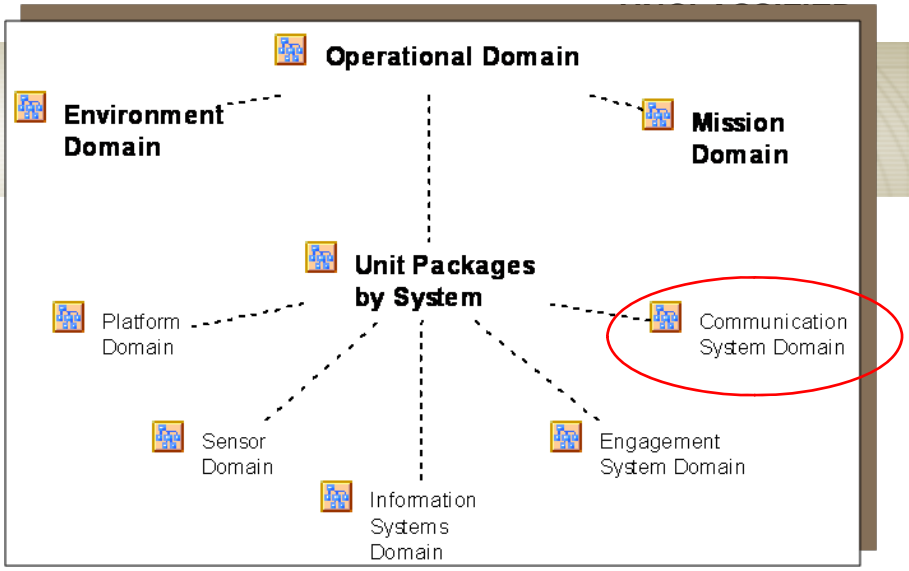
How to do it:

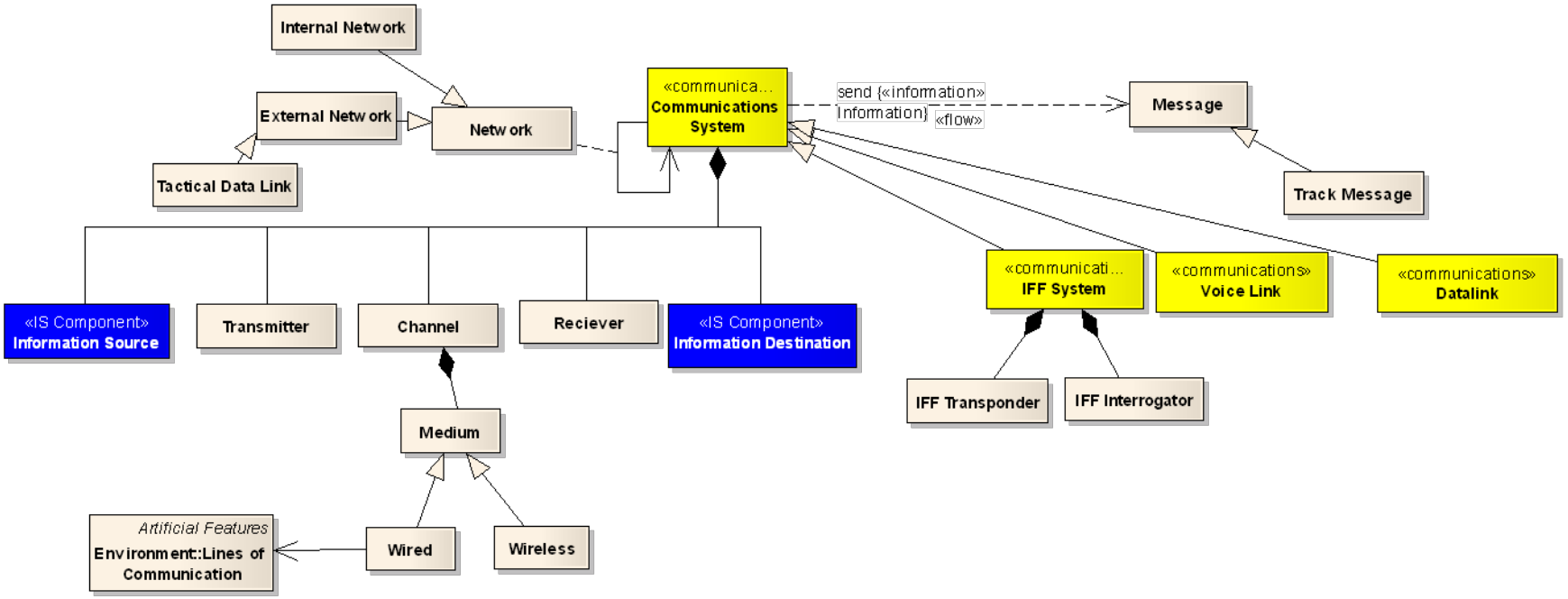
- **Informal requirements descriptions and mission descriptions.**
  - ***NOT* detailed, formal system requirements.**
  - **Generalized statements about system and what it does.**
- **CONOPS.**
- **Existing documentation.**
- **Stakeholder brainstorming sessions.**

What it is for: **Nouns extracted from these documents form a list of candidate domain entities.**

Domain Model (Example)

- High Level Domain covers environment, mission and systems-of-systems representations →→→→
- Expands to increasingly detailed system representations ↓↓





Why Use Domain Modeling?

- Standardize and define the problem space.
  - Use as a project glossary/naming convention.
  - Focus on real-world (problem domain) objects.
- Document domain structure.
  - Organize around key problem domain factors.
  - Encapsulate (sub) systems.
  - Simplify and/or standardize interfaces.
    - Identify systems and their interrelationships.
    - Enable analysis of the concepts.
- Provide critical foundation for follow-on conceptual modeling artifacts (e.g., use cases, activity models, state diagrams, M&S software design, etc.).

Complex systems-of-systems require a design approach that formalizes the mapping between behaviors and entities and remains flexible and resilient to change.

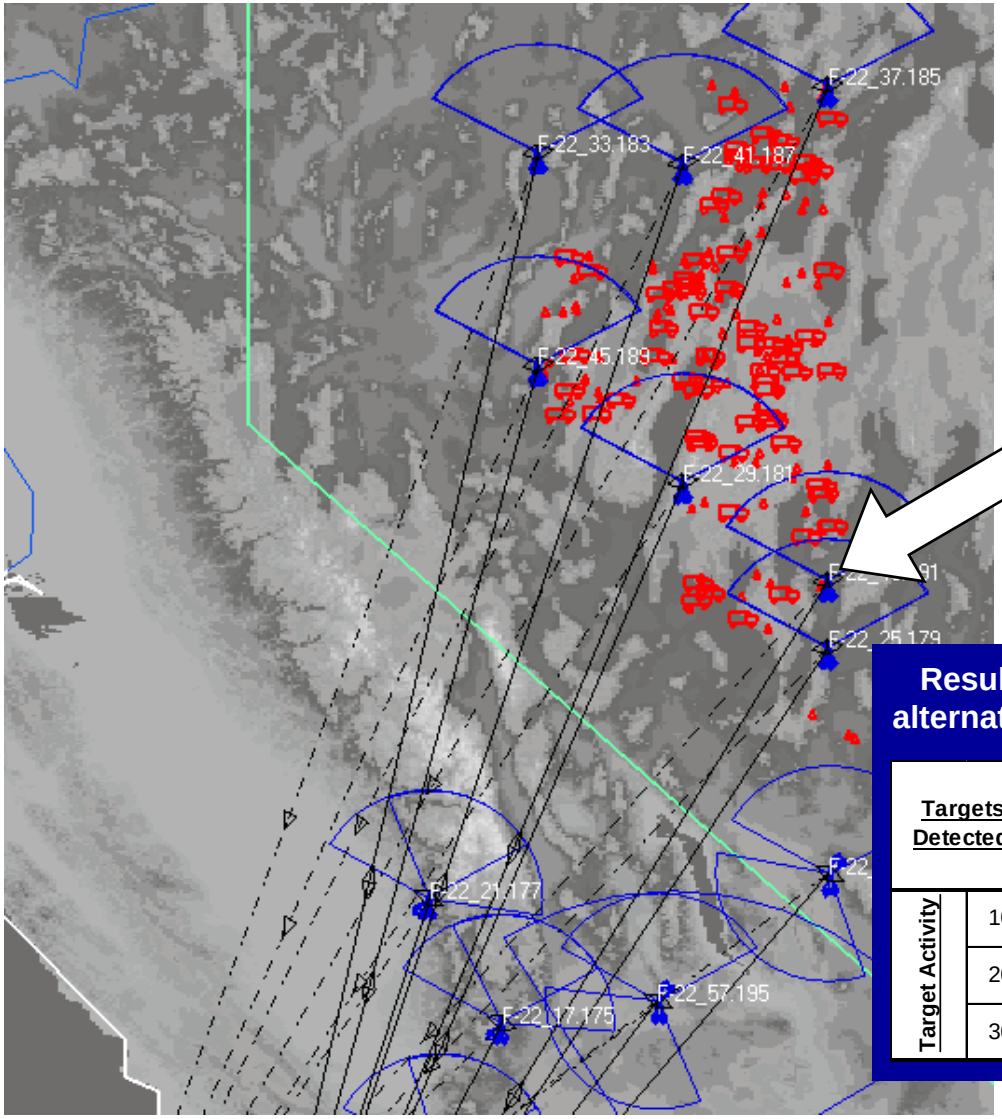
Domain Modeling and Other Project Tasks

- **The domain model is critical to the conceptual modeling tasks, through which it has important application across analysis and development projects:**
  - **Research, Development, and Analysis**
  - **M&S, Software Engineering**
  - **Systems Engineering, Architecture**
  - **Business Processes, Project Management**

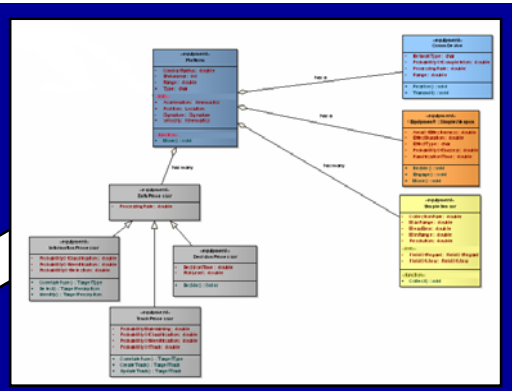
Why It Matters: Research, Development & Analysis

- Establishes framework for factor identification and selection including:
  - Structure: defines systems and capabilities.
  - Behavior: defines functional processes.
- Defines the domain entities each group must focus on to achieve their objectives.
  - There will be overlap identified – requiring coordination.
- Provides the terminology and factors for development of:
  - Tests and experiments including specification of alternatives and trades, and scenario development requirements.
  - System functions which emerge from domain entities: methods, attributes, and interfaces.
- Supports analysis at different levels of abstraction/fidelity without changing the underlying model/architecture.

Analysis Example



- Analysis factors are selected using domain entities and derived artifacts.
- Selection is independent of simulation tool.



Simulation implementation is defined by the class structure based on the domain model.

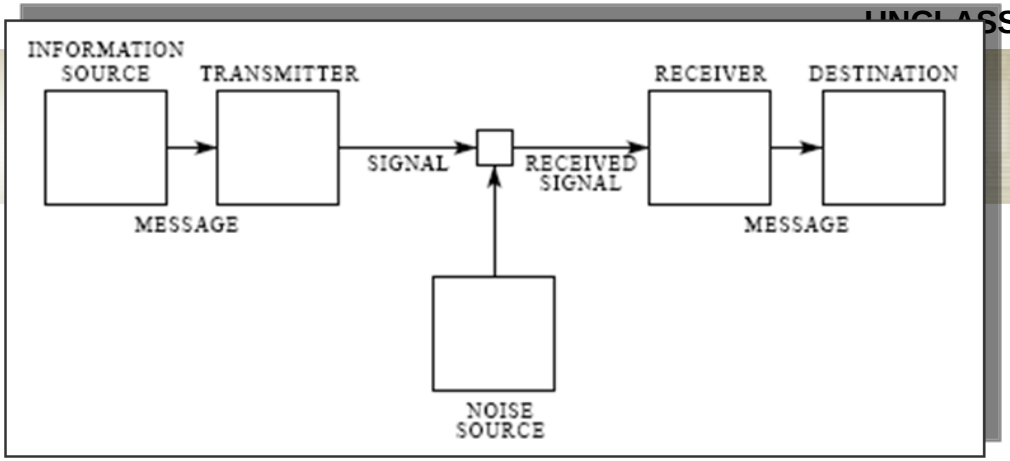
Results provide assessment of the efficacy of the system alternatives and the sensitivity of the factors on one another.

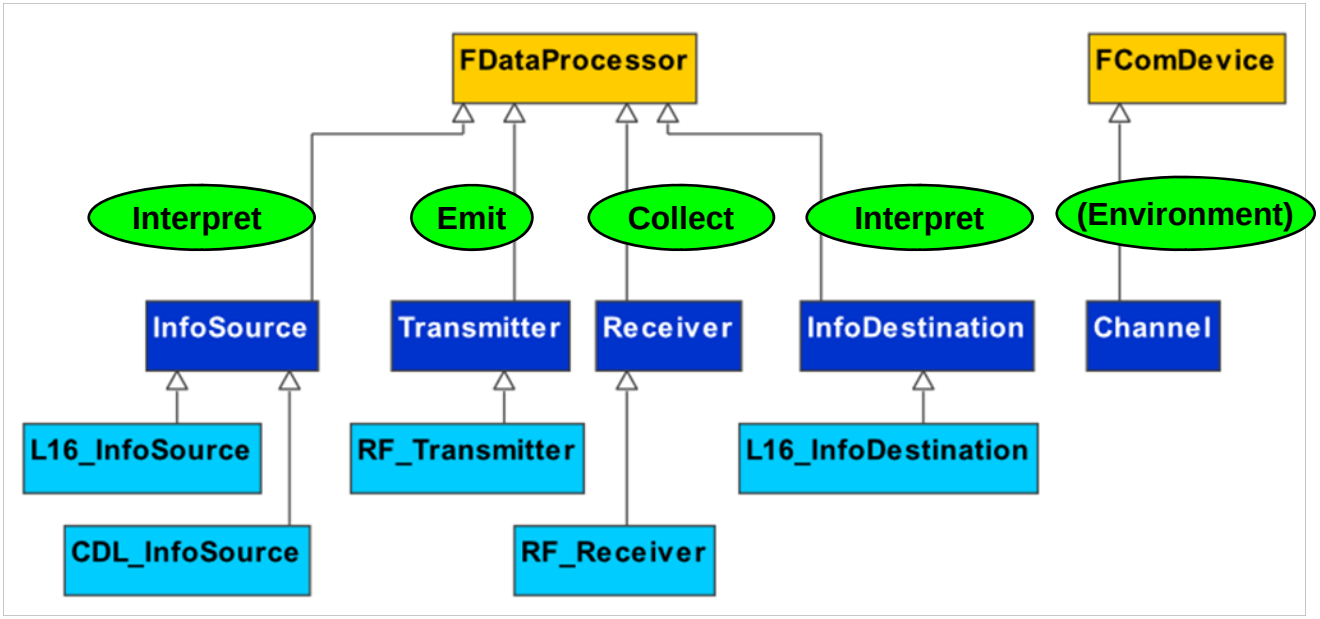
Targets Detected		Comm Throughput								
		0.3			0.5			0.7		
		Collection Capability								
		0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7
Target Activity	10	60	60	55	61	52	53	56	61	64
	20	58	66	80	69	80	65	75	69	76
	30	73	62	61	74	73	71	73	75	75

Why It Matters: Model and Simulation, S/W Eng.

- Helps identify where M&S software should be developed.
- Represents the top level classes and associations for M&S design.
  - Forms a foundation for software design model (UML).
  - Models are derived, developed, or specified from the domain-level superclasses.
- Enables assessment of complex network-centric issues via reusability, extensibility, and re-configurability of models.
- Identifies M&S needs/requirements for potential assignment to available tools (including legacy simulations).
  - i.e., once a simulation need is identified, existing tools can be evaluated against it.

M&S Example





Sim Framework Basic Types

Metamodel Activities

Generic Model Classes

Inherited Model Classes

- Domain entity becomes class for model implementation.
- Model parameters used to compose system representation.
- Domain artifacts provide basis for evaluation of existing simulations.

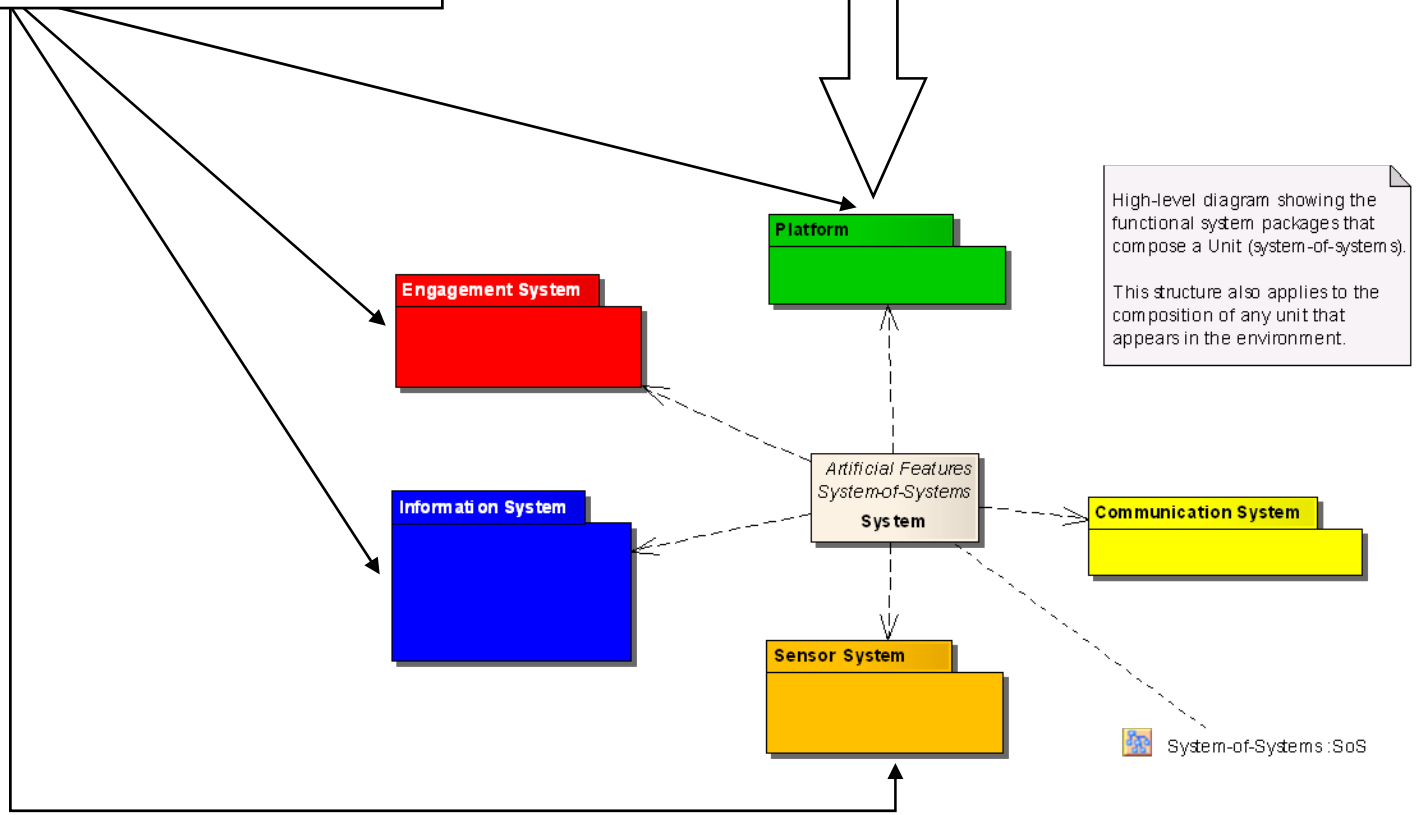
Why It Matters: Systems Engineering

- Tracks overall system-of-systems development and interactions.
- Provides insight into the system/subsystem alternatives.
- Useful as a foundation for system architectures.
- Supports requirements development/refinement.
- Identifies redundant or superfluous systems/processes.
- Simplifies design.
- Identifies capability shortfalls.
- Identifies program risks:
  - Technical readiness,
  - Interoperability challenges,
  - Critical technologies.
- Stored in a database, which can be linked to other SE products.

Systems Engineering Example

Requirement: The system will engage advanced air-to-air and surface-to-air threats based on the rules of engagement.

Program Database: Requirements, domain model and other artifacts, MS&A information, project management info, etc.



Why It Matters: Business Processes

- Identifies:
  - Areas of responsibility for different stakeholders.
    - Maps to project Work Breakdown Structure.
  - Shortfalls in coverage/investments.
  - Return on investment and related tech maturity of individual systems.
  - Risks to the overall goals of the program.
- How is this done?
  - Each domain entity is related to activities supporting development of applications, data or products needed to accomplish objectives and goals.
- Represents a unified simulation-based acquisition process with all components interconnected via the UML-based architecture.

Business Process Example

Task Name	Duration	Start	Finish
Project X	**56 days**	**Wed 2/27/08**	**Wed 5/14/08**
Scenario Development	**56 days**	**Wed 2/27/08**	**Wed 5/14/08**
Identify Target Sets	**42 days**	**Wed 2/27/08**	**Thu 4/24/08**
Assess TCT characteristics	**4 days**	**Thu 4/24/08**	**Tue 4/29/08**
Scenario development	**11 days**	**Wed 4/30/08**	**Wed 5/14/08**
Intelligence Collection Process Design	**1 day**	**Thu 4/24/08**	**Thu 4/24/08**
Command and Contorl Process Design	**1 day**	**Thu 4/24/08**	**Thu 4/24/08**
Develop Baseline Processes/Metrics	1 day	Thu 4/24/08	Thu 4/24/08
Develop Advanced Processes	1 day	Thu 4/24/08	Thu 4/24/08
Engagement System Development	**1 day**	**Thu 4/24/08**	**Thu 4/24/08**
Develop assessment process	**1 day**	**Thu 4/24/08**	**Thu 4/24/08**
Model and Simulation Development	**1 day**	**Thu 4/24/08**	**Thu 4/24/08**
Select Model Environment	1 day	Thu 4/24/08	Thu 4/24/08
Unit Development	1 day	Thu 4/24/08	Thu 4/24/08
System Development	1 day	Thu 4/24/08	Thu 4/24/08
Sensor Development	1 day	Thu 4/24/08	Thu 4/24/08
Communications Development	1 day	Thu 4/24/08	Thu 4/24/08
Information System Development	1 day	Thu 4/24/08	Thu 4/24/08
Engagement System Development	1 day	Thu 4/24/08	Thu 4/24/08
Conduct Analysis	**1 day**	**Wed 2/27/08**	**Wed 2/27/08**
Write Report	**1 day**	**Wed 2/27/08**	**Wed 2/27/08**

- **Project's WBS and activities based on domain entities and follow-on artifacts.**
- **Enables improved governance.**
- **Enhances task estimation and risk assessment.**

Domain Modeling Assessment

Goods

- Replacement of legacy applications (incremental implementation)
- Gain understanding of current capabilities, analyze costs, compare w/ proposed replacement systems
- Make future programs more efficient
- Better risk management
- Potential for program-wide database or knowledge management system

- Reuse across portfolio
- Common foundation/linkages for program tasks (s/w and system engineering, analysis, business processes)
  → *CONVERGENCE*
- Standardization
- Greater accessibility to stakeholders
- Lasting documentation (domain longevity)
- Tool/simulation/code agnostic

Others

- Up-front costs
- Understanding new tools, language, processes
- Personnel and skillset availability

- Inertia of DoD acquisition practices
- Cultural resistance

Summary -- Domain Modeling:

- **Is fundamental to conceptual model development, which itself is a crucial activity in large and complex projects.**
- **Is not a new idea, though it is (perhaps) under-utilized in the DoD community.**
- **Enables discovery of relationships between entities within the domain and analysis of technical problems.**
- **Results in a robust, relatively invariant model applicable across related domains.**
- **Facilitates linkage of diverse projects and processes into a unified portfolio.**
- **Increases efficiency of acquisition processes through flexibility and reusability.**
- **Provides a common foundation for M&S, architecture, analysis, and project management tasks . . .**

→ Convergence

Sources

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ROSENBERG, D., AND SCOTT, K. 2001. Driving Design: The Problem Domain. *Dr. Dobb's Journal*.

ROSENBERG, D., AND STEPHENS, M. 2007. *Use Case Driven Object Modeling with UML.* Apress, Berkeley, CA.

Questions?

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"It is far better to grasp the Universe as it really is than to persist in delusion, however satisfying and reassuring."

- Carl Sagan (1934-1996)

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Backups


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Use Cases

What it is: **Descriptions of interactions between the system and its users.**

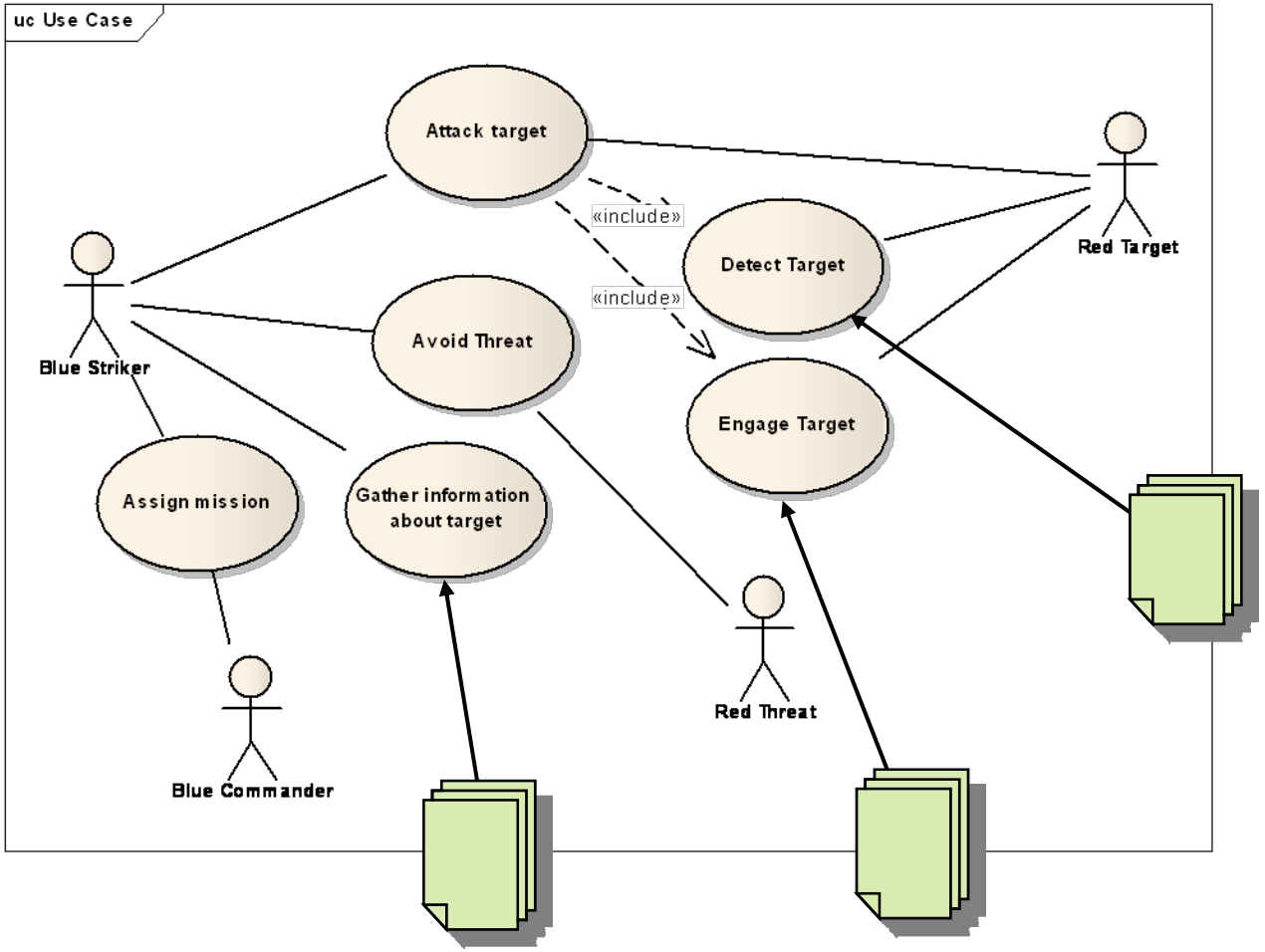
How to do it:

- **Identify**
  - **The actors – users of the system, including other systems.**
  - **The tasks facilitated by the system.**
  - **The actors' participation in the tasks, including alternate courses of events.**
- ***Use vocabulary previously defined in domain model*.**
- ***Go back and alter the domain model as errors are uncovered through use case exploration.***

What it is for:

- **Answers the question, "What are the user experiences with the system?"**
- **Helps define scope and provides general basis for more formal modeling.**
- ***Provides foundation for the dynamic behavioral model.***

Use Case (Example)



- Use cases are listed in a diagram showing the participating actors.
- Each use case is expanded into a document describing the flow of events involved, including:
  - Actors involved
  - Preconditions
  - Event sequences
  - Exceptions
  - Participants
  - Alternatives
  - Unresolved issues

Class Model

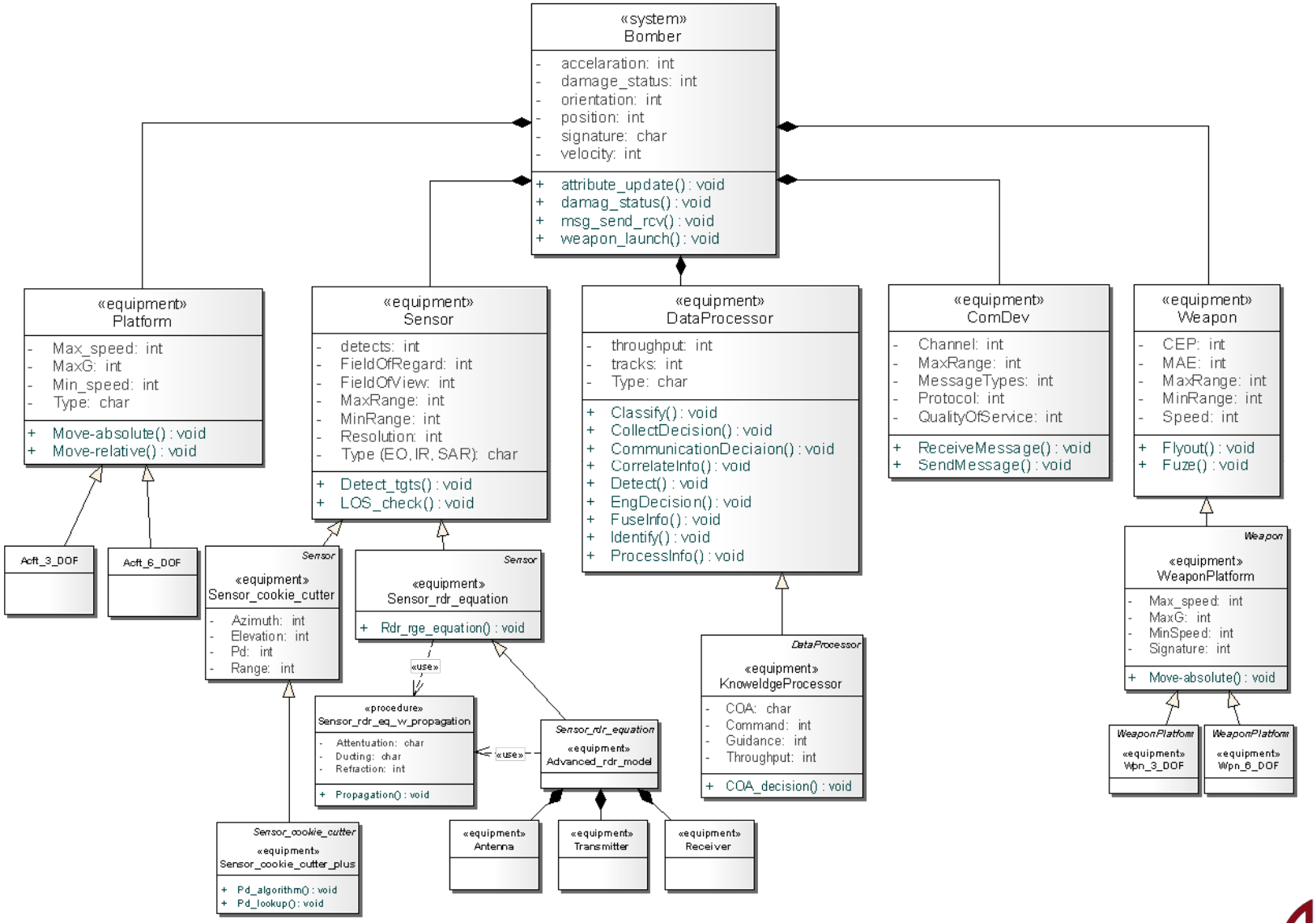
What it is: **A more detailed static representation of the domain.**

How to do it:

- ***Extend the domain model.***
- **Allocate behaviors to domain model entities based on use case descriptions.**
- **Add attributes and operations to domain model entities.**
- **Add classes to the solution space as necessary.**
- **Work iteratively, going back and forth between static model and behavioral model (e.g., activity, sequence diagrams).**

What it is for: **Begins to translate general descriptions into more formal system design.**

Class Model (Example)



Activity, State, other Behavioral Diagrams

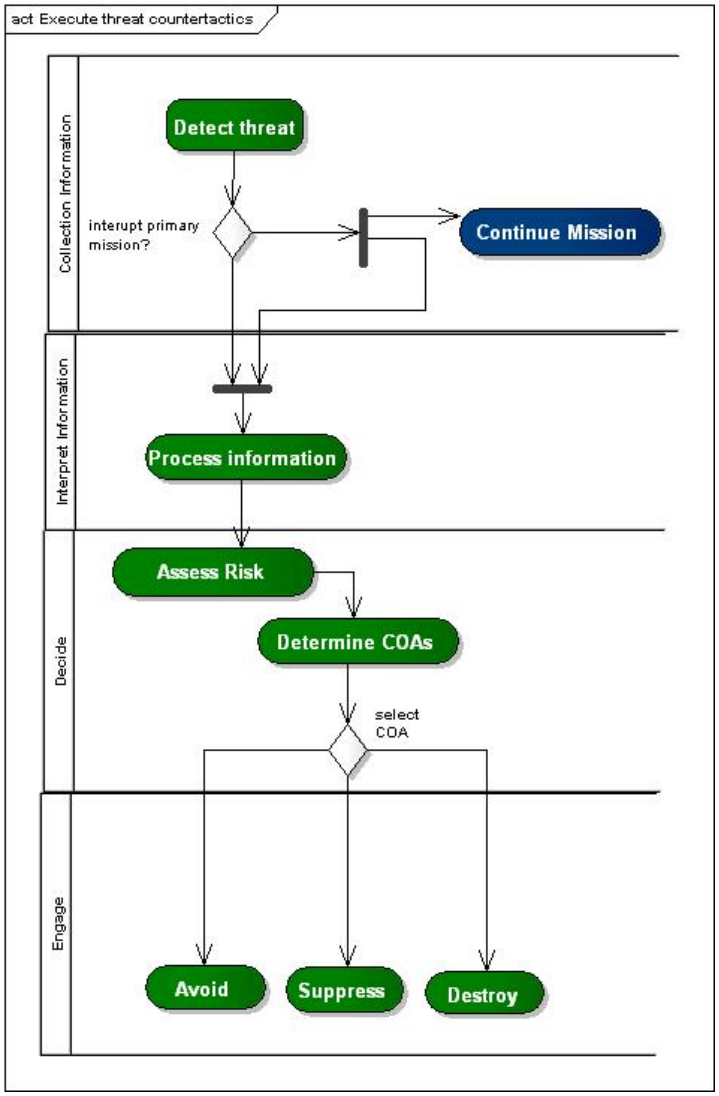
What it is: **A more detailed dynamic representation of the system.**

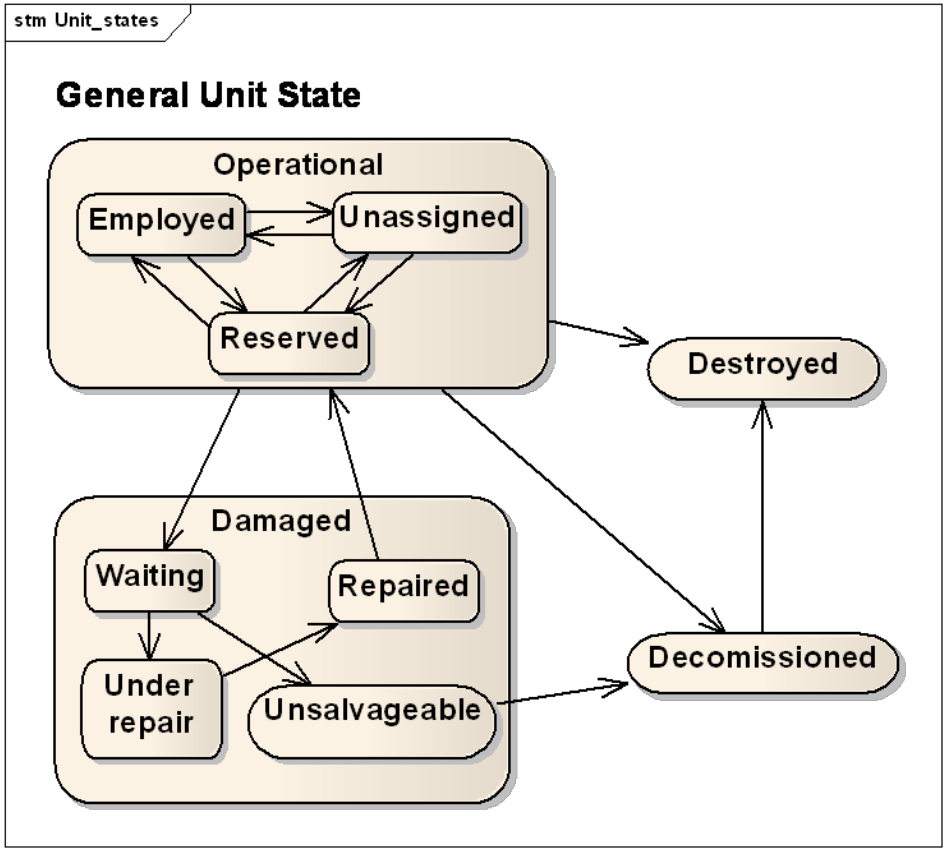
How to do it:

- **Create activity diagrams:**
  - **Break up use cases into component transactions or activities.**
  - **Sequence the activities.**
  - **Assign responsibility for each activity to a domain entity via swimlanes.**
- **Create state diagrams:**
  - **Define atomic states for each domain entity.**
  - **Sequence the states.**
  - **Define conditions and constraints governing state transitions.**
- **Use the use cases as a primary input.**
- **Work iteratively, going back and forth between the behavioral model and the static model (domain and class model), ensuring compatibility.**

What it is for: **Begins to formalize use cases into more detailed system behaviors and activities.**

Behavioral Model (Example)





- State Diagram
- Activity Diagram