Experiences in Applying SysML to Develop Interoperable Torpedo Modeling and Simulation Components

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Newport, RI

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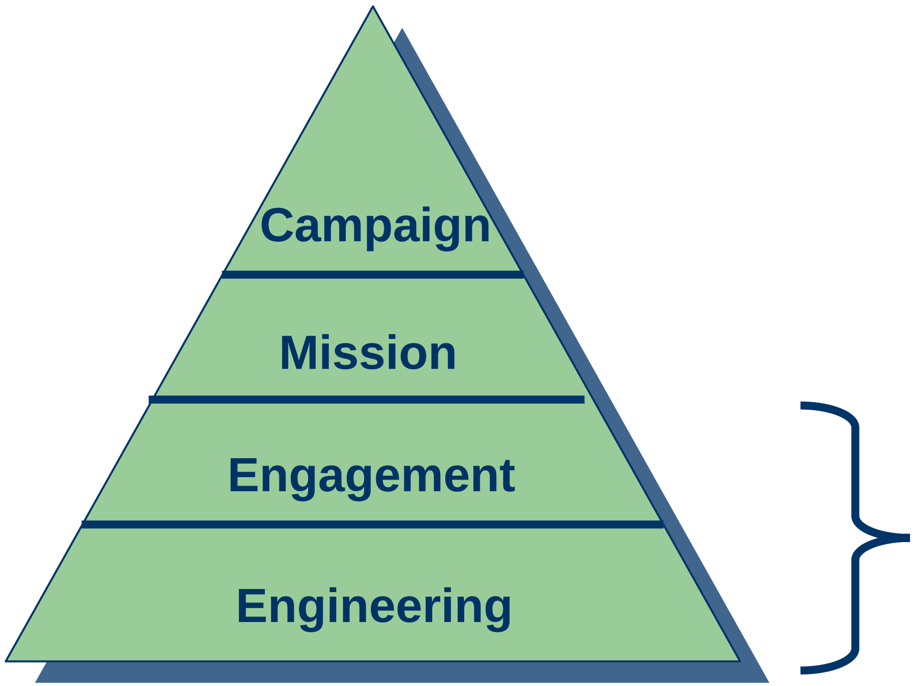
Outline

- SysML Case Study Motivation
- TEAMS Project Background
- SysML Proof of Concept
- Lessons Learned
- TEAMS Perspective: SysML Pros and Cons
- Acknowledgements

Motivation: Feasibility of Open Standards

- Funded by Office of Secretary of Defense, Systems and Software Engineering
- Determine if open standards can be used to describe:
  - System of systems (SoS) architectures based on computer models
  - System components as elements of composable distributed simulations
- Determine whether SysML models can be used in conjunction with performance simulation models

Background: TEAMS Simulation Scope



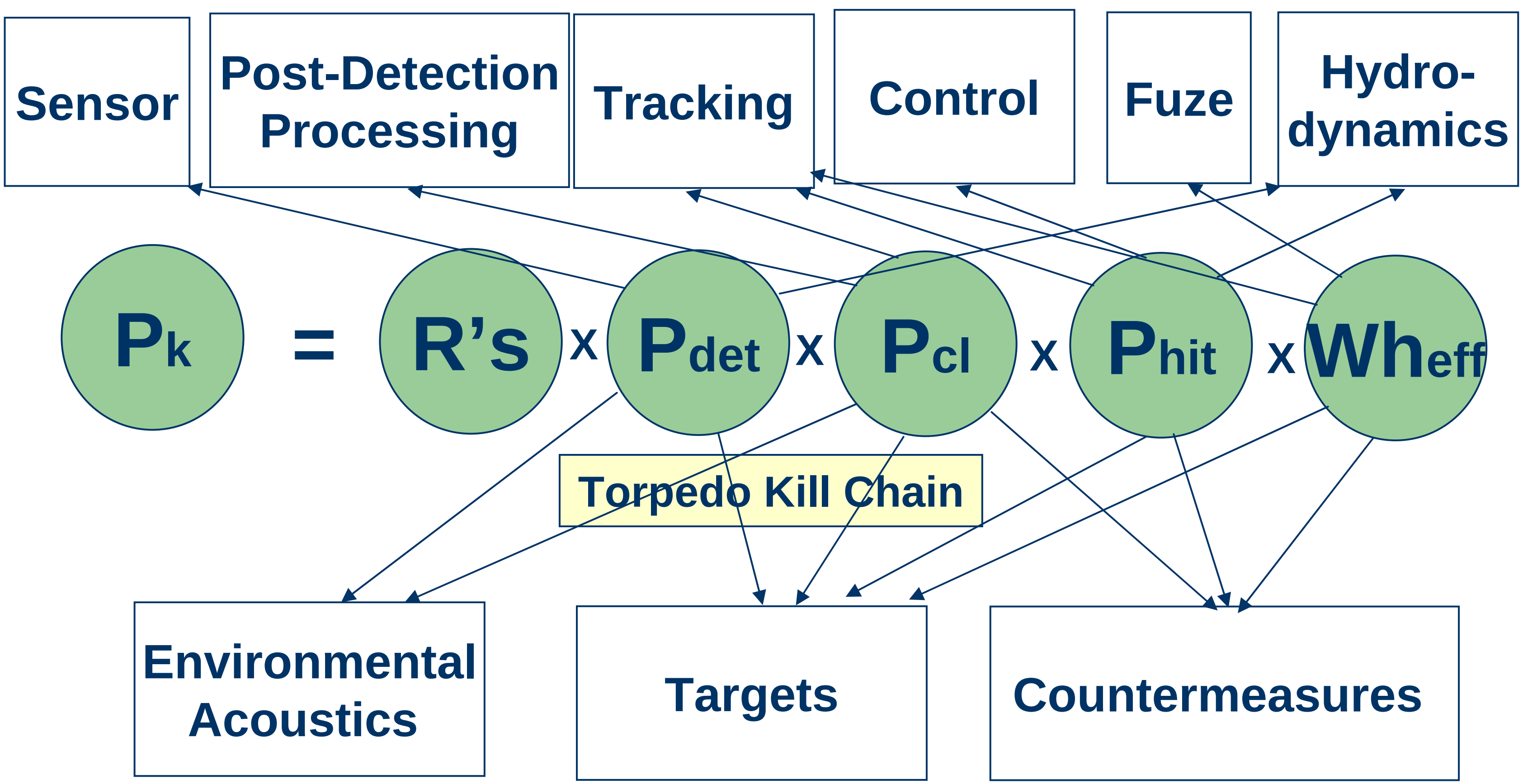
TEAMS Emphasis: “Launch-to-Hit” Analysis

Military M&S Resolution Levels

TEAMS: Torpedo Enterprise Advanced Modeling & Simulation

Background: High-Level M&S Requirements

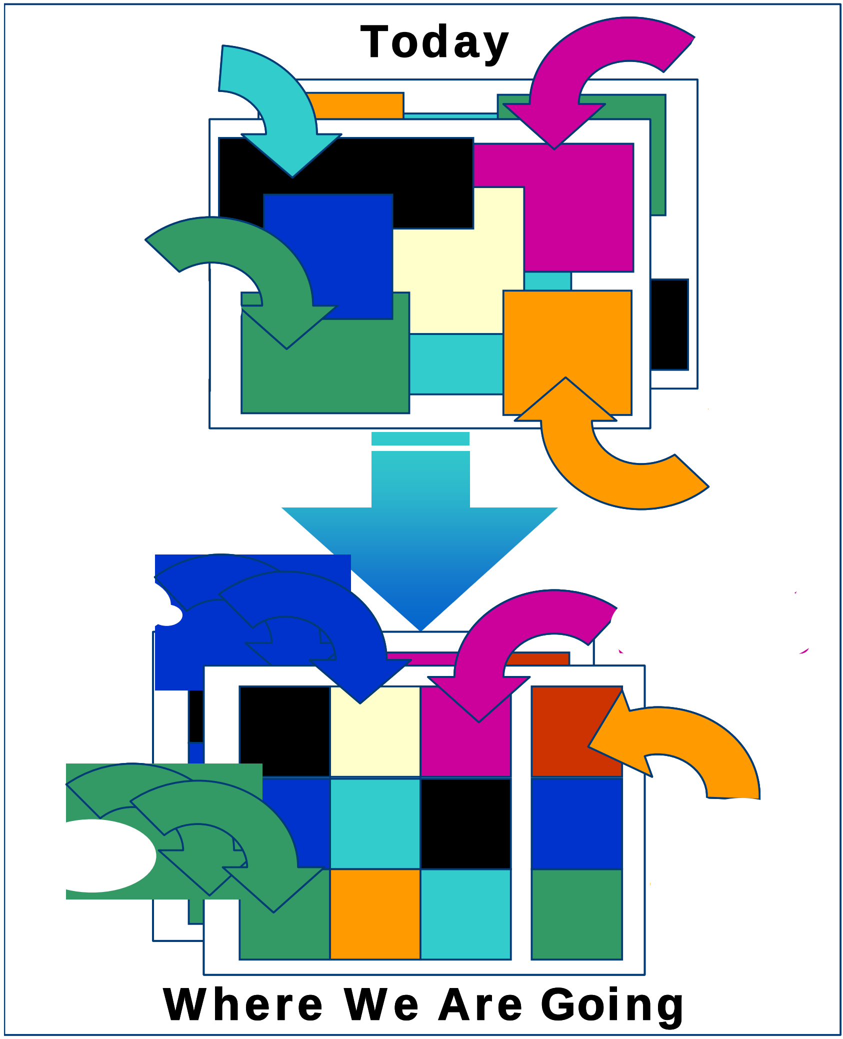
Torpedo M&S Components



Other "Stimulus" M&S Components

TEAMS Background

- **Problem: Modeling & Simulation Business "Model" Obsolete**
  - Monolithic
  - Stove pipes
  - Single developers
  - No communication
- **Solution: Foster Collaborative M&S Development Environment**
  - Standardize M&S architecture framework and component models
  - Reduce the technology development timeline
  - Increase model content, implementation efficiency and reuse
  - Reduce cost



Overall TEAMS Goals

- Modeling and Simulation Community Collaboration
- Standardized architecture framework
  - Conceptual reference model
  - Model-based requirements specifications
- Standardized reference model interfaces
  - Interchangeable & composible components
  - Extendable to other applications (e.g., XML schema)
  - Semantically described (e.g., OWL ontology)
- Document standards and requirements
- Cost effective process to achieve interoperability and composability
- Business model for future cross-organization M&S funded efforts

TEAMS Core Requirements

1. Standard Interfaces
2. Platform Independence
3. Open Standards
4. Model Realizable Systems
5. Extensible Interfaces
6. Evolving Standards
7. Loosely Coupled Interfaces
8. Tiers of Interfaces
9. Support Different Levels of Detail
10. Standard Implementation Strategies

Organizations Looking to TEAMS

THE Open GROUP

International organization, developers of TOGAF architectural framework

- Wants TEAMS as test case for TOGAF 8.1.1 and 9.0

- Interest in using TEAMS to test synergy between DoDAF and TOGAF frameworks

- Wants TEAMS for its process to incorporate Ontologies (relationships of components)

OMG® OBJECT MANAGEMENT GROUP

International organization, developers of several business communications standards

- Used TEAMS as test case for their TOGAF/ Model Driven Architecture (MDA) under the TOGAF/MDA Synergy Project

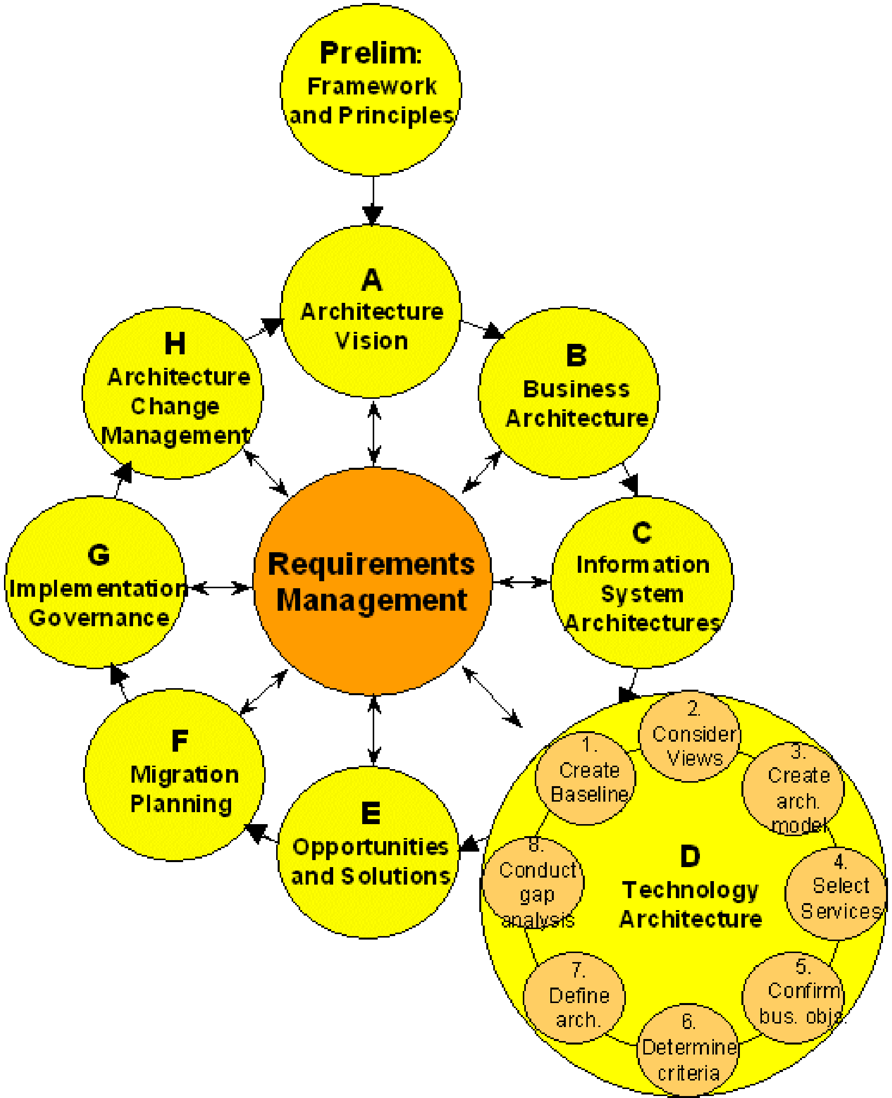
OPEN SYSTEMS OS JOINT TASK FORCE

The Open Systems Joint Task Force of the Office of Secretary of Defense (OSD)

- Wants to convert TEAMS UML artifacts to the newly approved SysML standard to demonstrate utility of the new standard

TEAMS is quickly yielding *highly visible* and *transitionable* results.

High-Level Process: TOGAF ADM



The Open Group: IT Consortium Offers Consortia Services

TOGAF: The Open Group Architecture Framework

ADM: Architecture Development Method

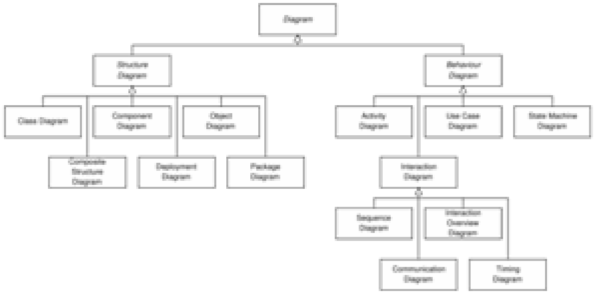
"OMG™ is [a] … not-for-profit computer industry consortium … developing enterprise integration standards for a wide range of technologies [… / …] industries … enabl[ing] powerful visual design, execution and maintenance of software and other processes…"

- CORBA – Common Object Request Broker
- UML – Unified Modeling Language
- SysML – Systems Engineering Modeling Language
- Numerous others in diverse industries (e.g., business)
- Developer of Model Driven Architecture (MDA) method

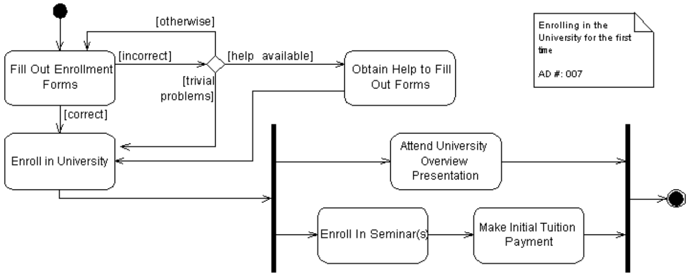
OMG has a model-based emphasis in developing standards

UML

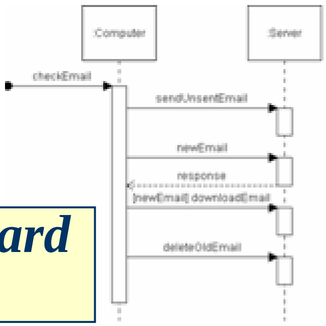
UML Consists of 13 Diagrams



Structure: E.g., Class Diagram



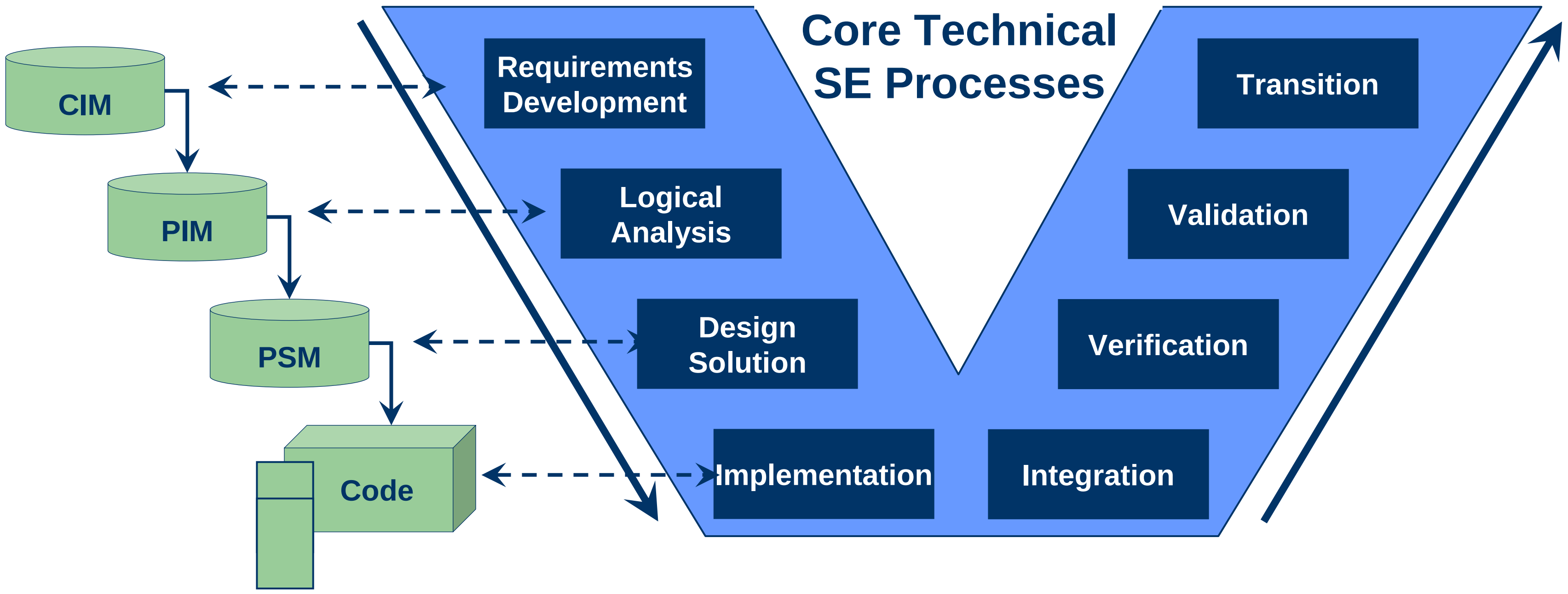
Behavior: E.g., Activity Diagram



Interaction: E.g., Sequence Diagram

OMG models are MOF-Based - Meta-Object Facility Standard
Think "TurboTax"

Using MDA in SE Context

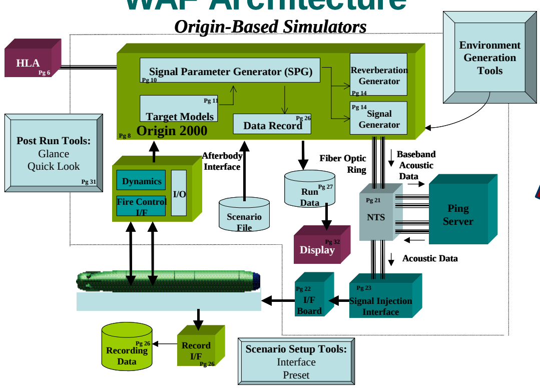


The implementation (code) for technology selected by the developer

Baseline Technology Architecture

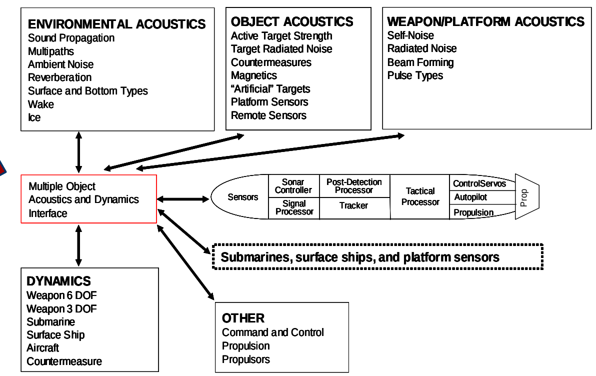
Weapons Analysis Facility (WAF)

WAF Architecture



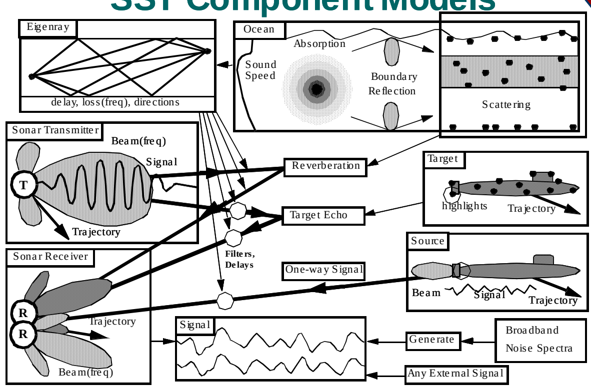
Technology Requirements Model (TRM)

TRM's CARLEE



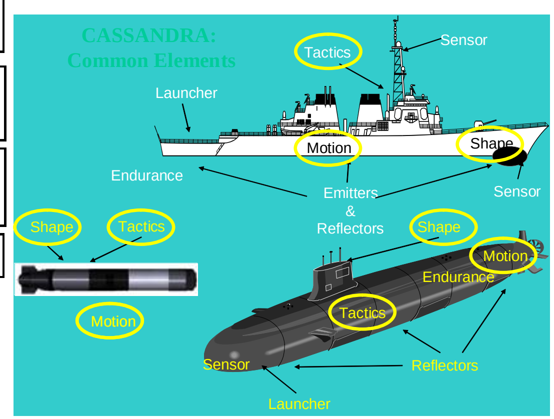
Conceptual Reference Model

SST Component Models

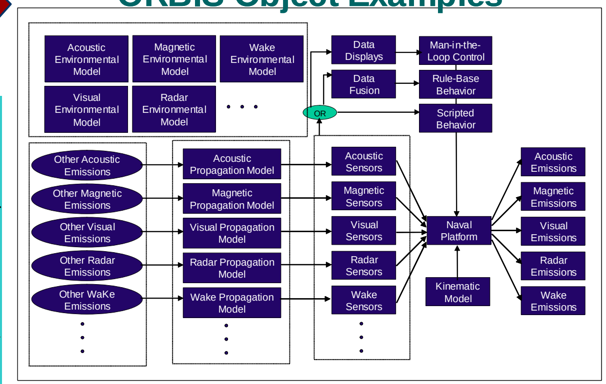


Sonar System Toolset (SST)

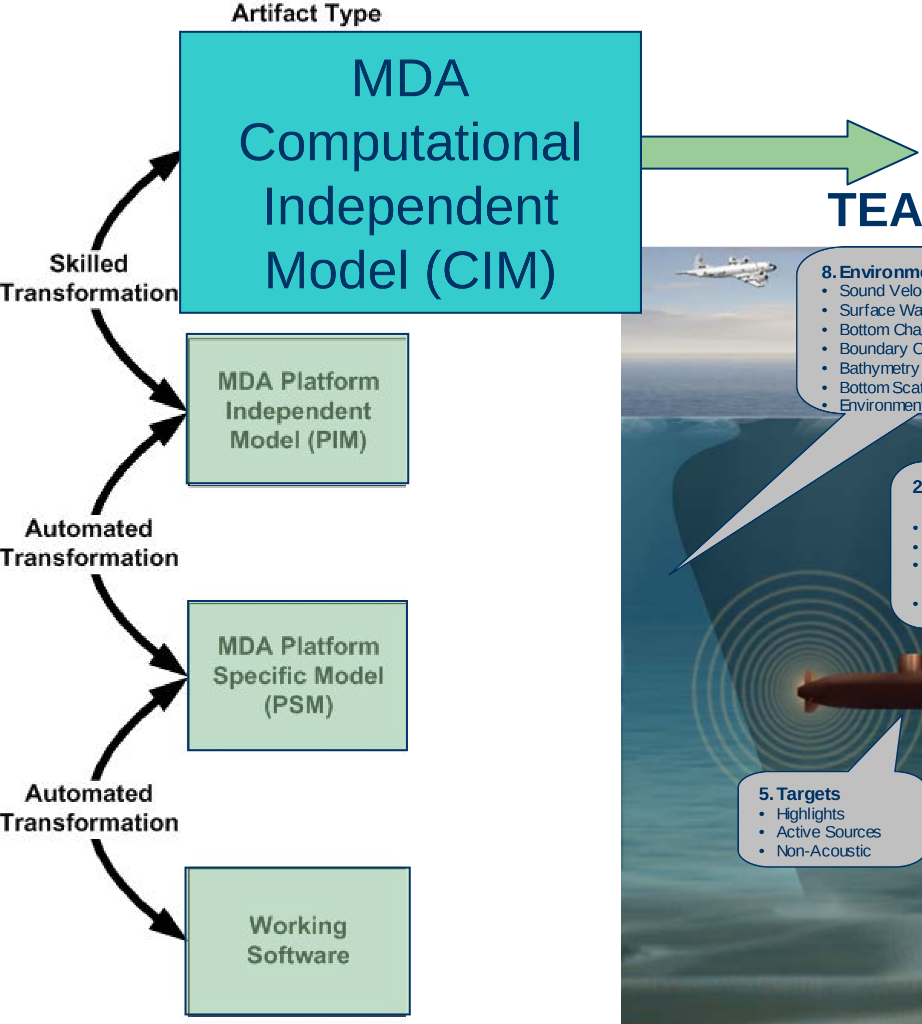
CASSANDRA Common Elements



ORBIS Object Examples



The Method:
Model Driven Architecture (MDA)



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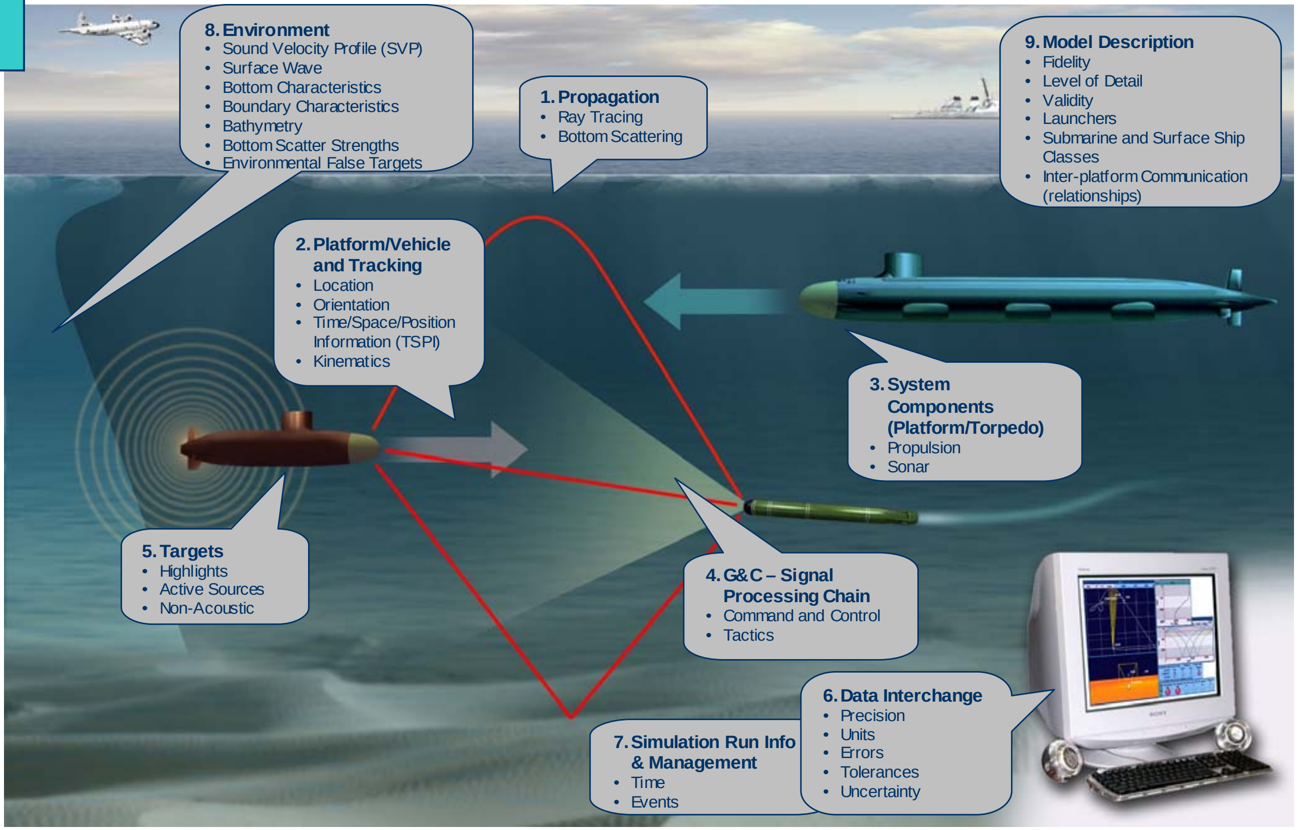

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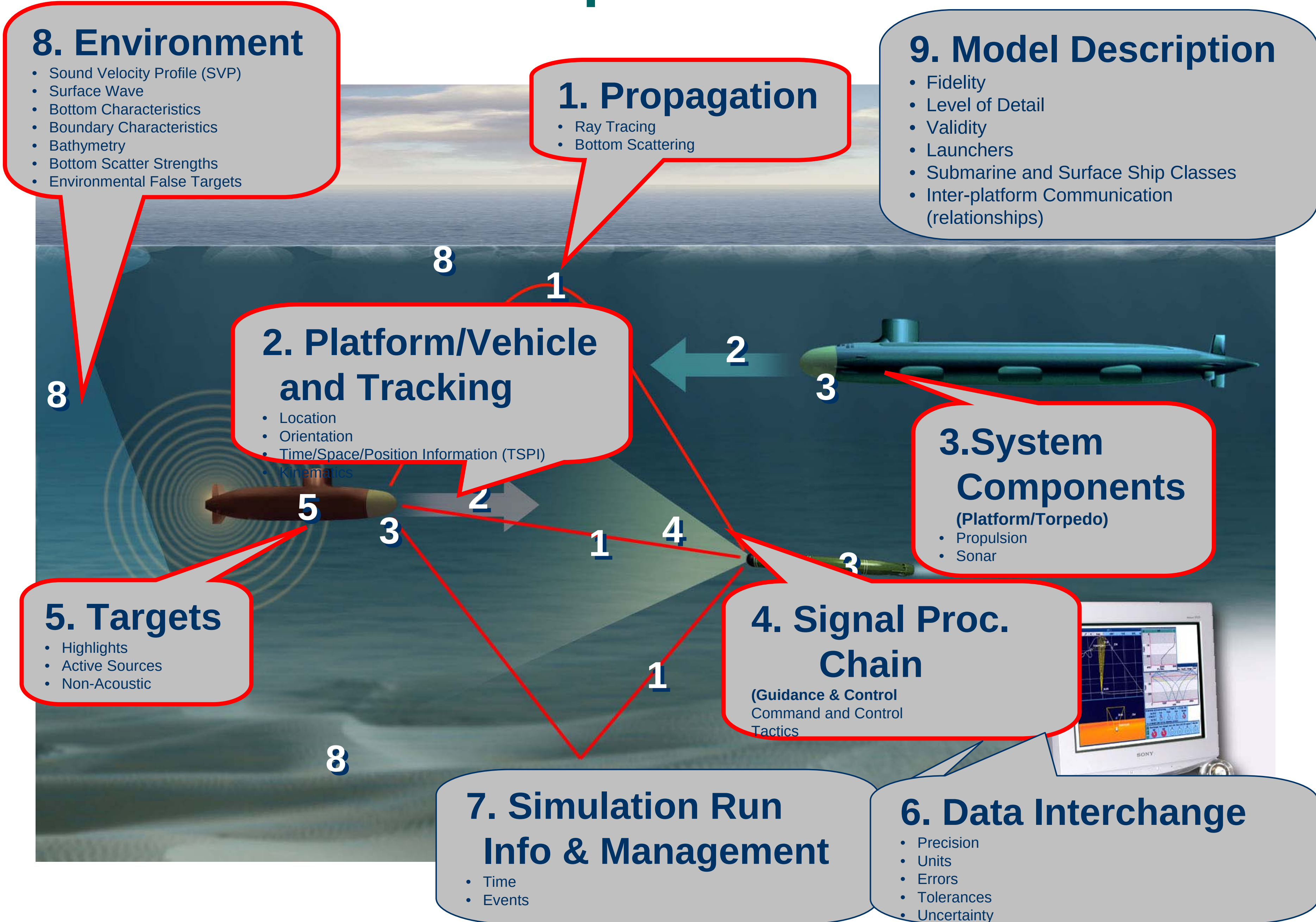
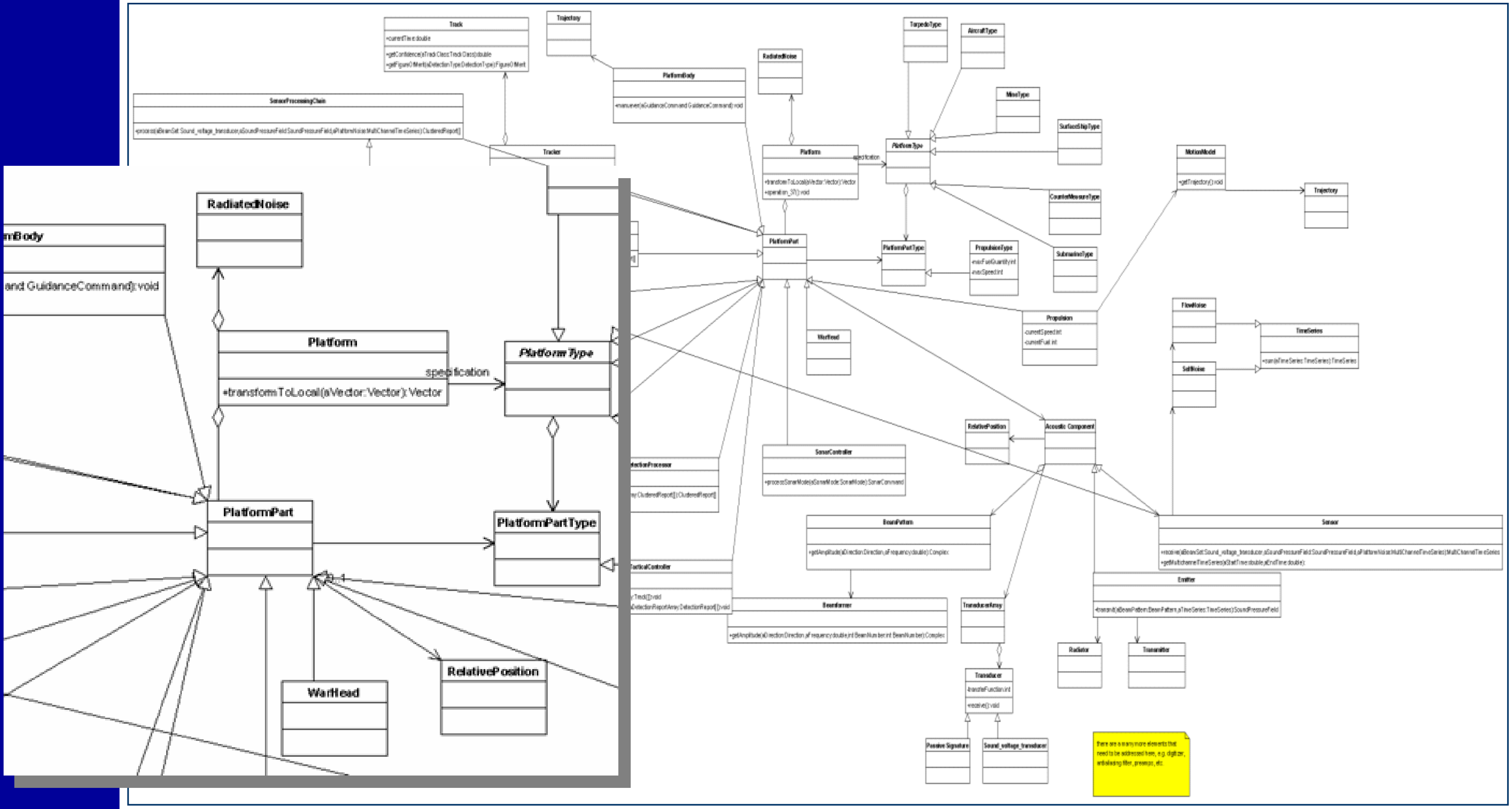
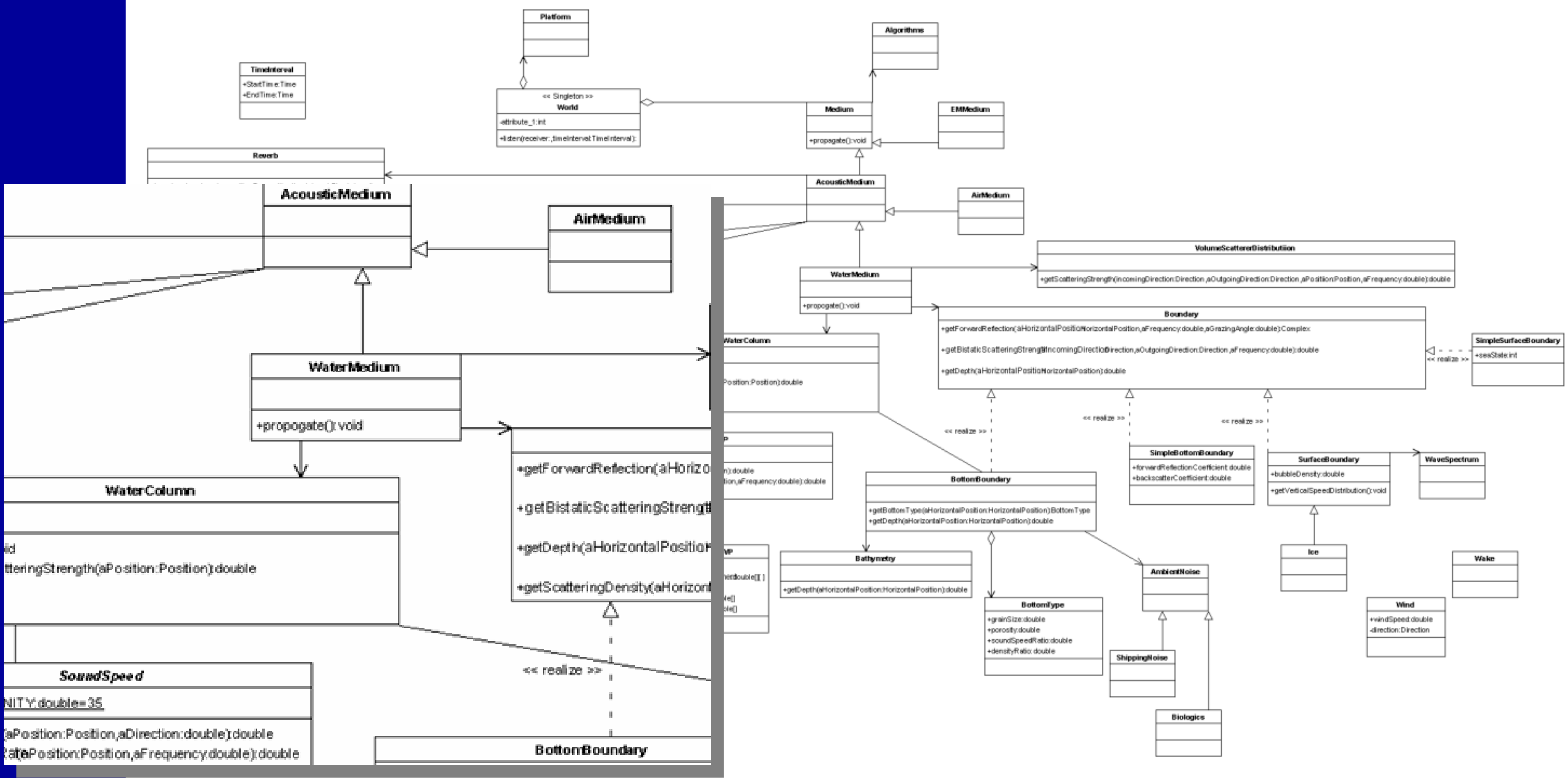


Platform Conceptual Level Diagram



Environment
Conceptual Level Diagram



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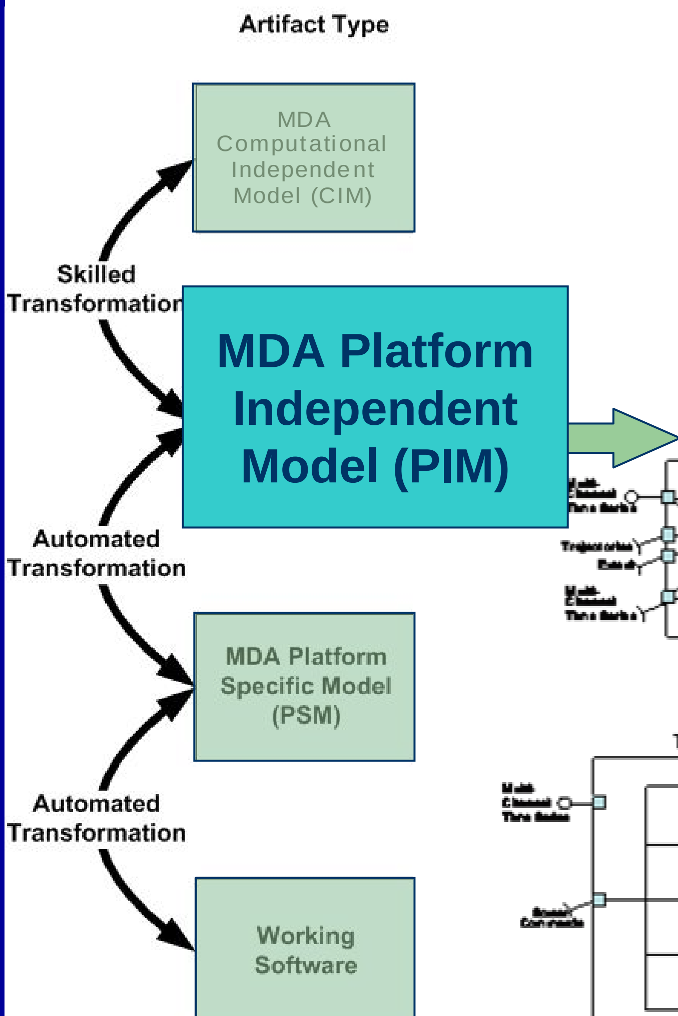
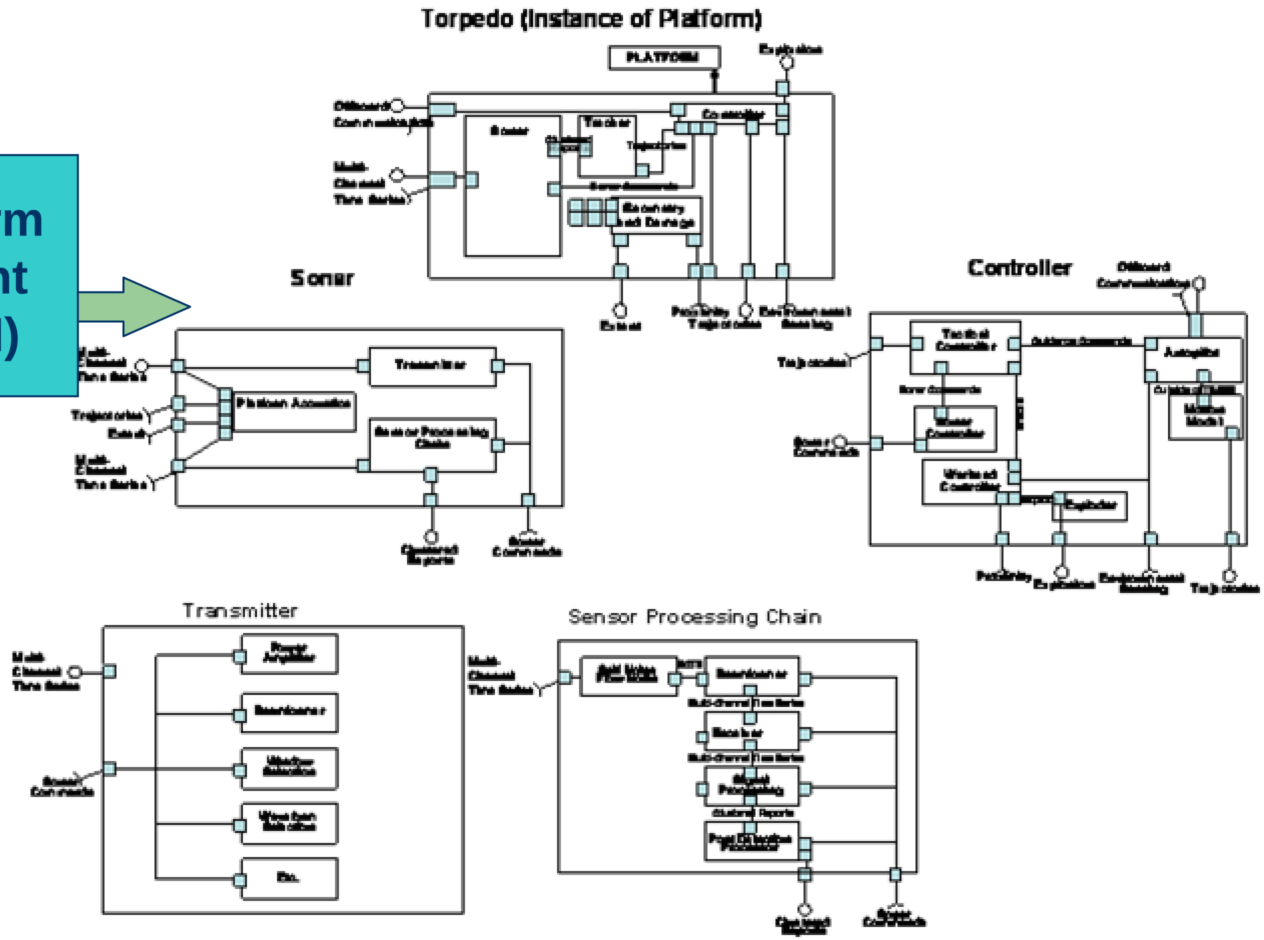
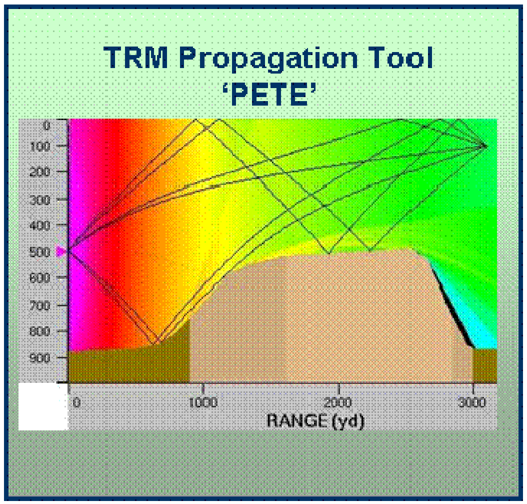


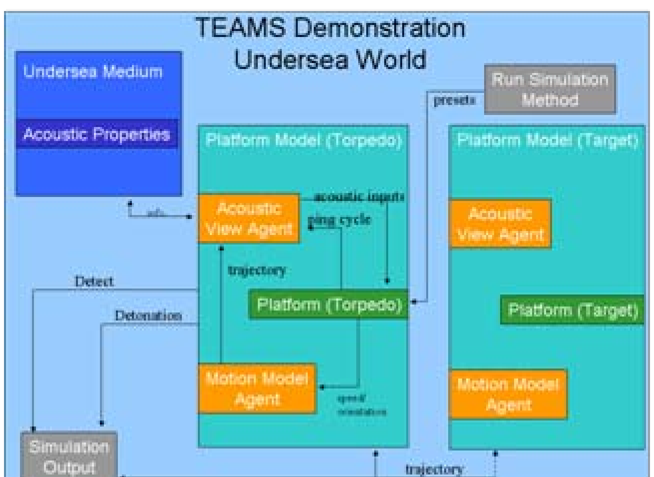
TEAMS UML Component Diagrams (Now Represented in SysML)



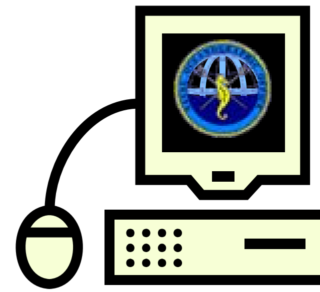
TEAMS PSM: Implementation

Reference Implementations





In-situ Environmental Data via Web Services



NAVOCEANO SIPRNET Web Site

Jackson Bottom Model via CORBA

Applied Physics Lab University of Washington

Closed-Loop SimuLink™ Torpedo, Environment & Target

PMS 404
UNDERSEA WEAPONS PROGRAM OFFICE

TEAMS SysML Proof of Concept

- Port existing UML to SysML
  - Torpedo system components
  - Simulation environment
- Extend TEAMS SysML to include:
  - Requirements traceability
  - Parametrics and constraints
- Share experiences and lessons learned using SysML for architecture and component modeling

UML to SysML Approach

- **Convert UML Class Diagrams to SysML Block Definition Diagrams (BDDs)**
- **Convert UML Component Diagrams to SysML Internal Block Diagrams (IBDs)**
- **Represent Behavior Relationships Between Blocks as Activity Diagrams *(new!)***
- **Capture Requirements Traceability *(new!)***
- **Capture Parametric Relationships and Constraints *(new!)***

TEAMS Perspective: SysML Pros and Cons

Pros

- Requirements
  - Explicitly lay out requirements and consequences
- Views and Viewpoints
  - Can separate requirements and model views based on stakeholders concerns
- Structure
  - Ability for model structure to verify requirements
    - Can search for requirements that aren't verified
    - Can search for model components that aren't justified
  - Separation of structure from behavior
    - SysML BDDs vs. IBDs and Activities allow for clear separation
    - UML allows this, but easier to implement in SysML
- Behavior
  - Dashed line for activity flow is more aesthetically pleasing
    - vs. UML solid line

Cons

- Allocating CIM to PIM
  - Difficulty with abstract activities
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Sponsor Requirements

req SponsorRequirements [SponsorReqts]

Reduced Duplicate Efforts

notes

Different contractors should not have to research the same technology or enabling model in order to accomplish their specific goals. Instead, similar efforts should be merged together and the result shared.

Less Component Integration Time

notes

Component developers should be able to spend their time and resources on developing, and be able to verify new ideas with simulation quickly.

Model Realizable Systems

notes

Component developments need to be convertible into a real system to be useful.

Contractor Interoperability

notes

If two different contractors write two different components, they should be able to communicate with each other.

Reuse Legacy and New Components

notes

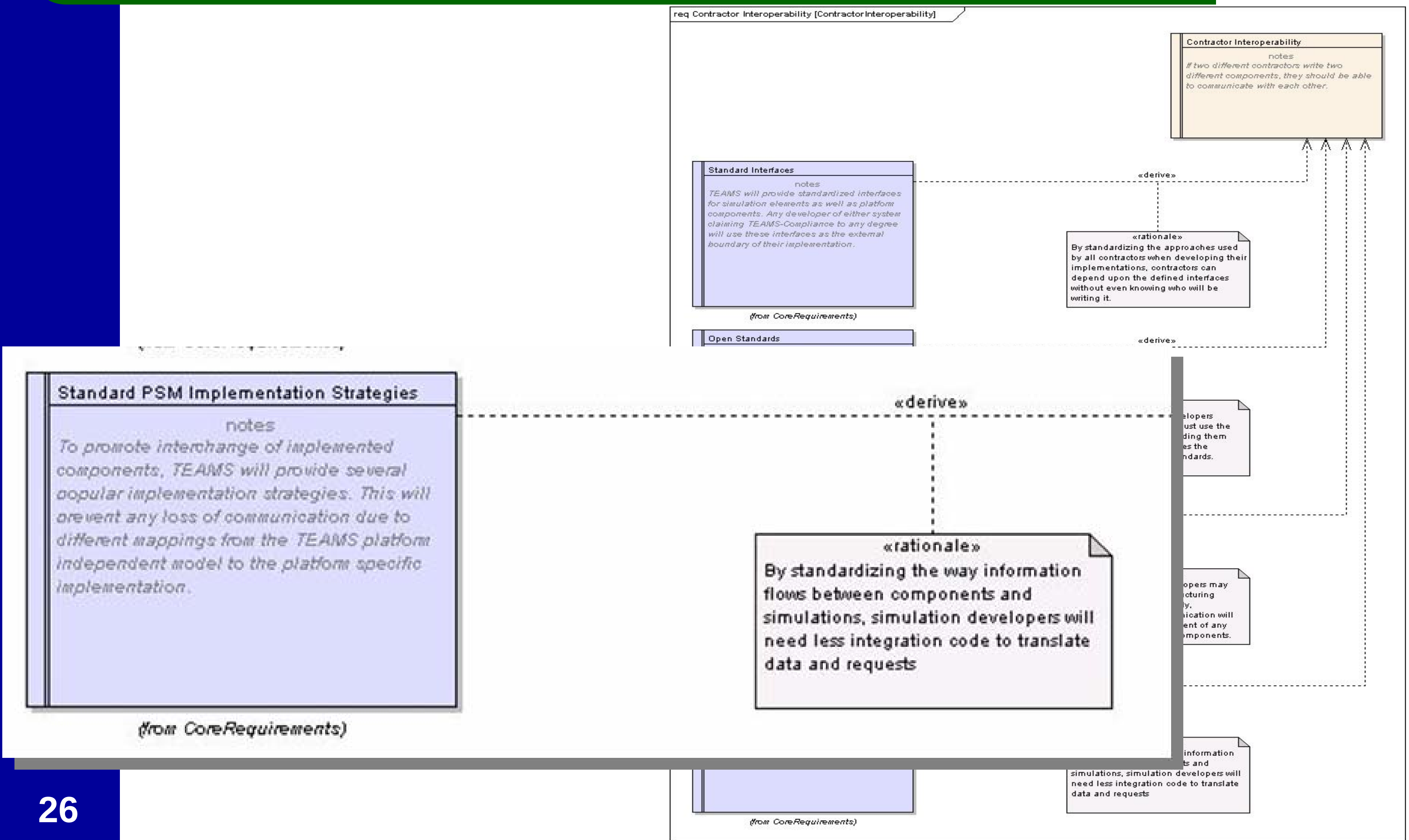
Some mechanism should enable older systems to be pulled into simulations with new interfaces, and newly developed components should have some easily reusable interface to reduce this problem in the future.

Room for Future Growth

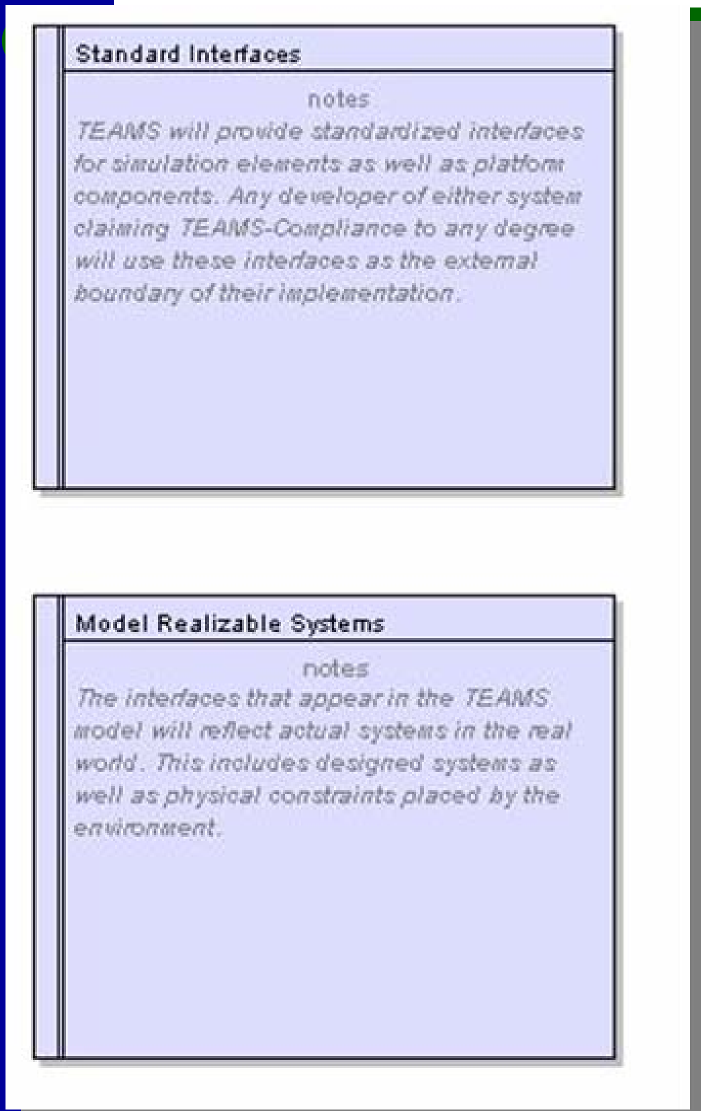
notes

Adaptivity to future changes is important in any large initial investment, including standardization of components. There is a risk of the standards being out of date before they have enough time to be useful.

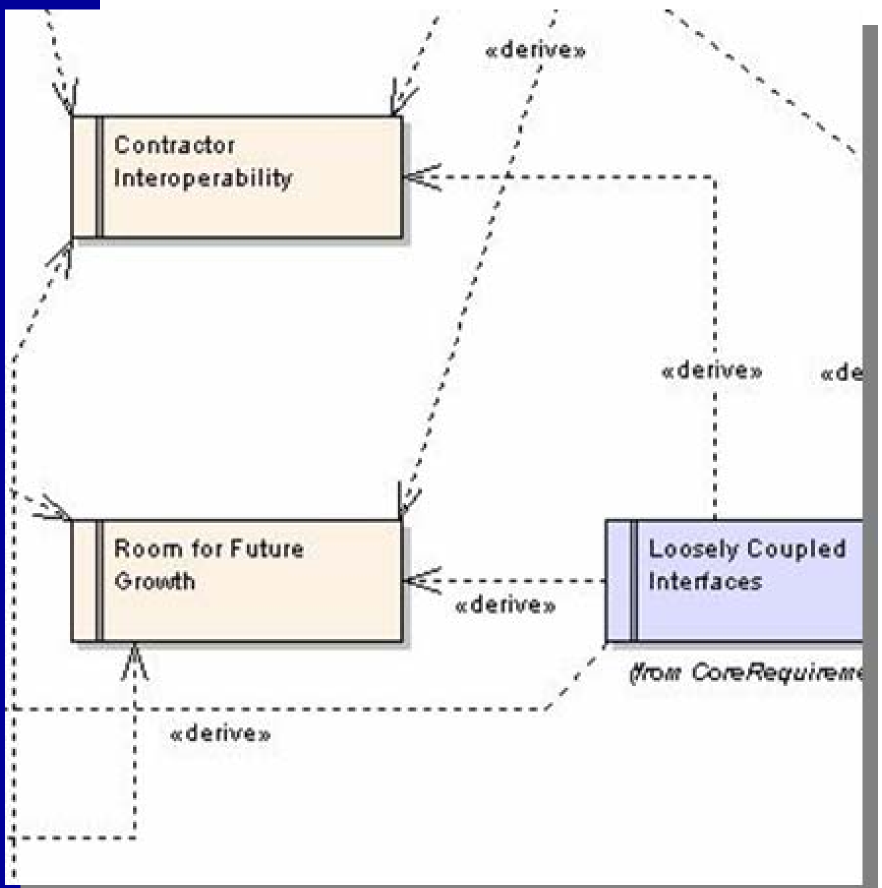
Rationale for Deriving TEAMS Core Values from Sponsor Requirement(s)

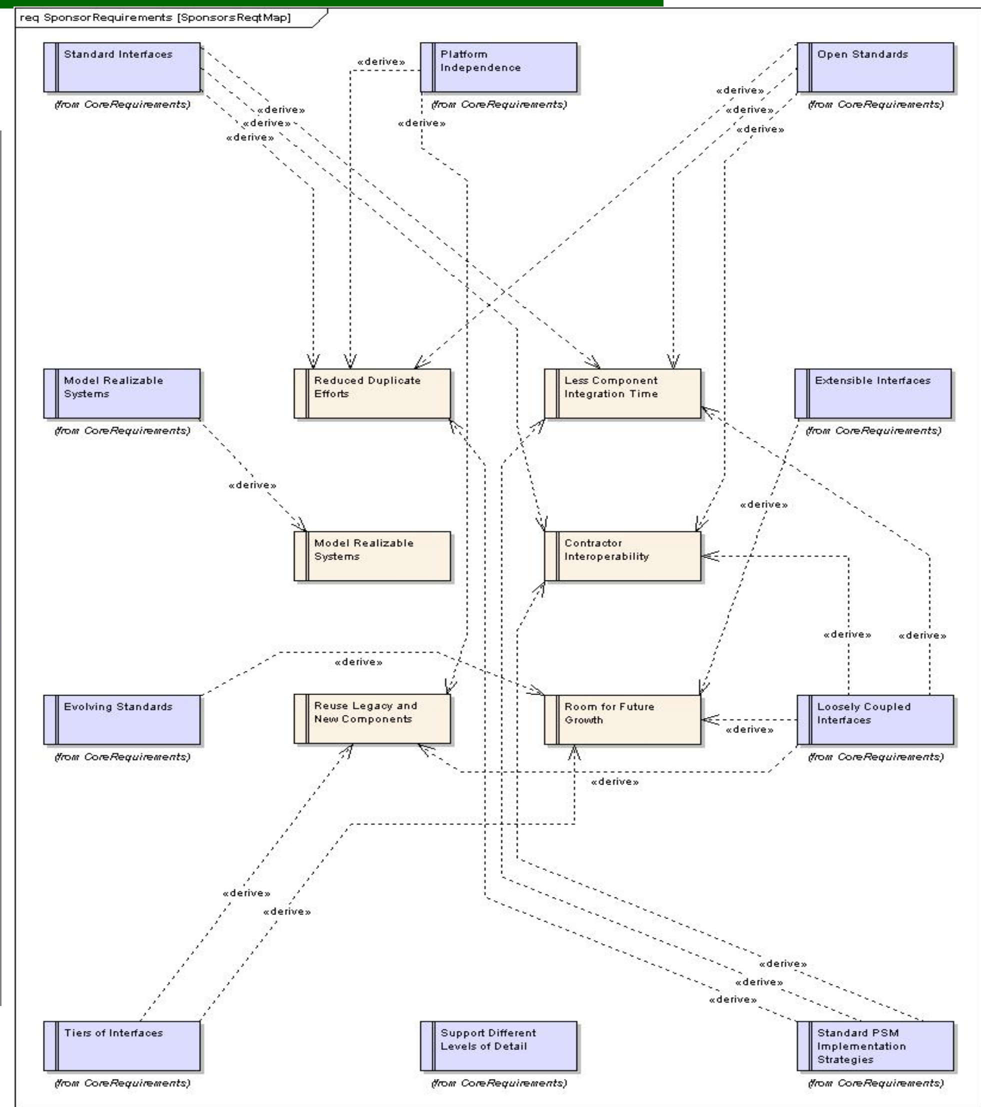


Requirements Traceability: TEAMS Core Values



Sponsor Requirements Mapped to TEAMS Core Values





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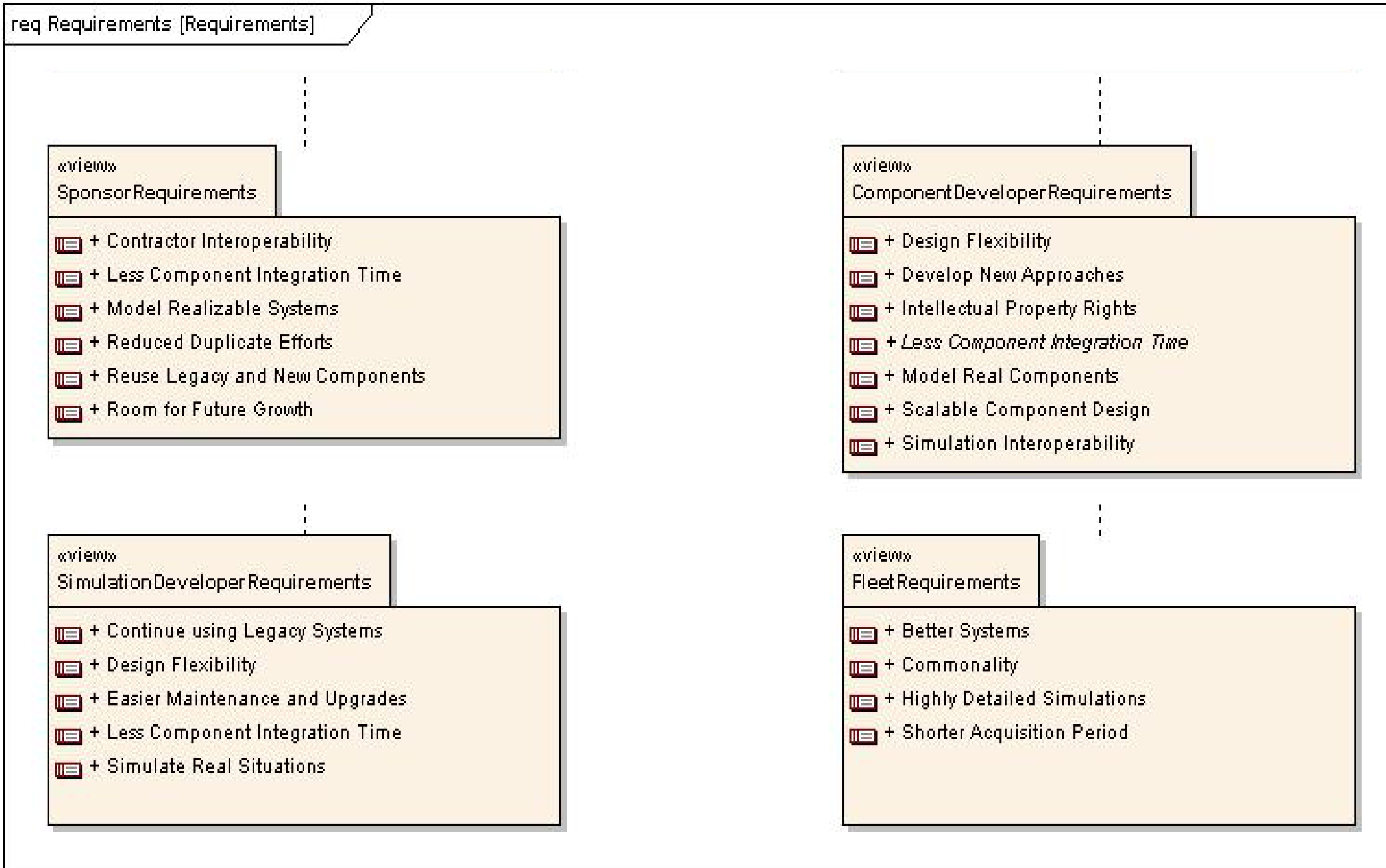
TEAMS
Stakeholder Requirements



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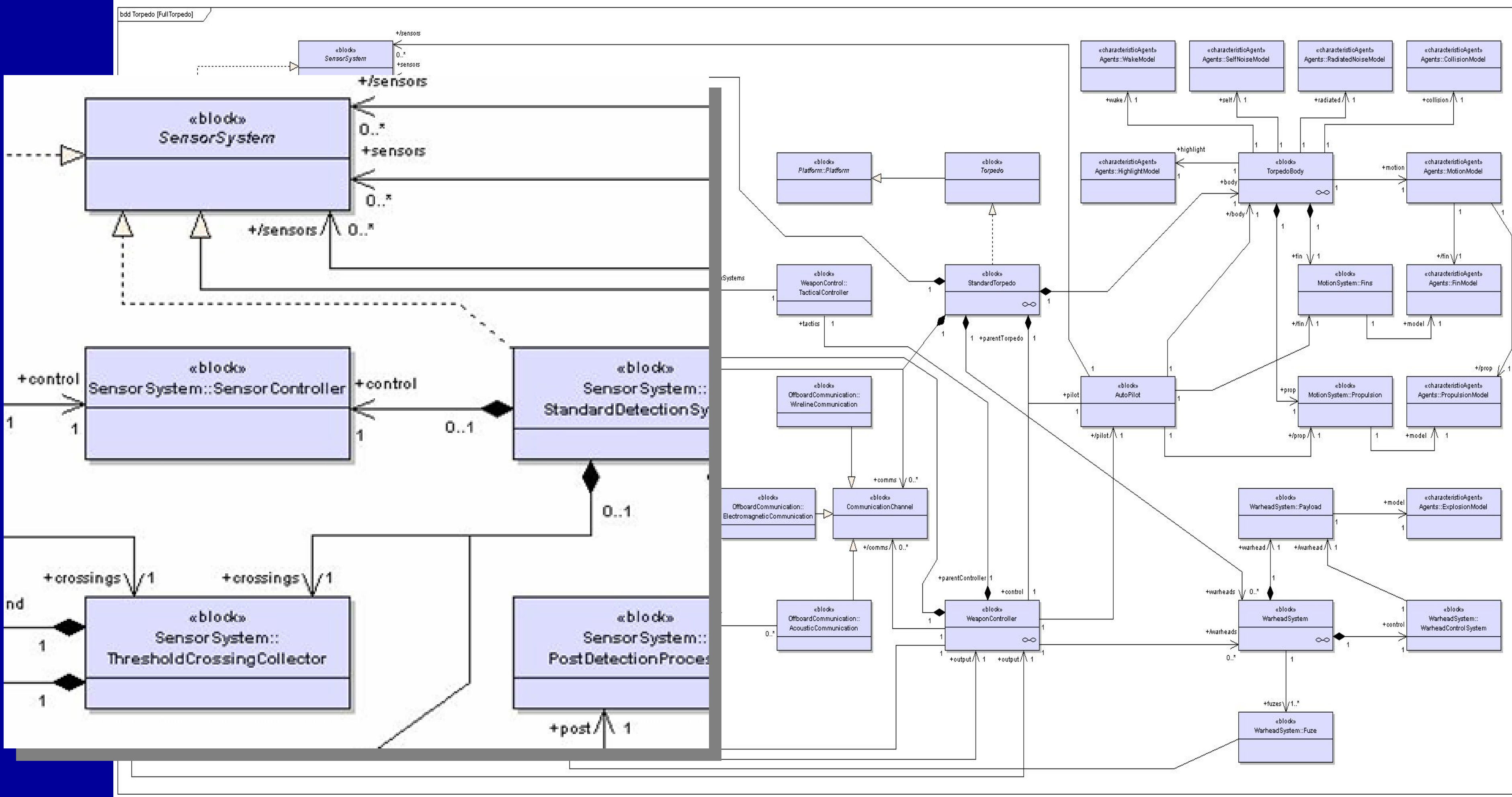
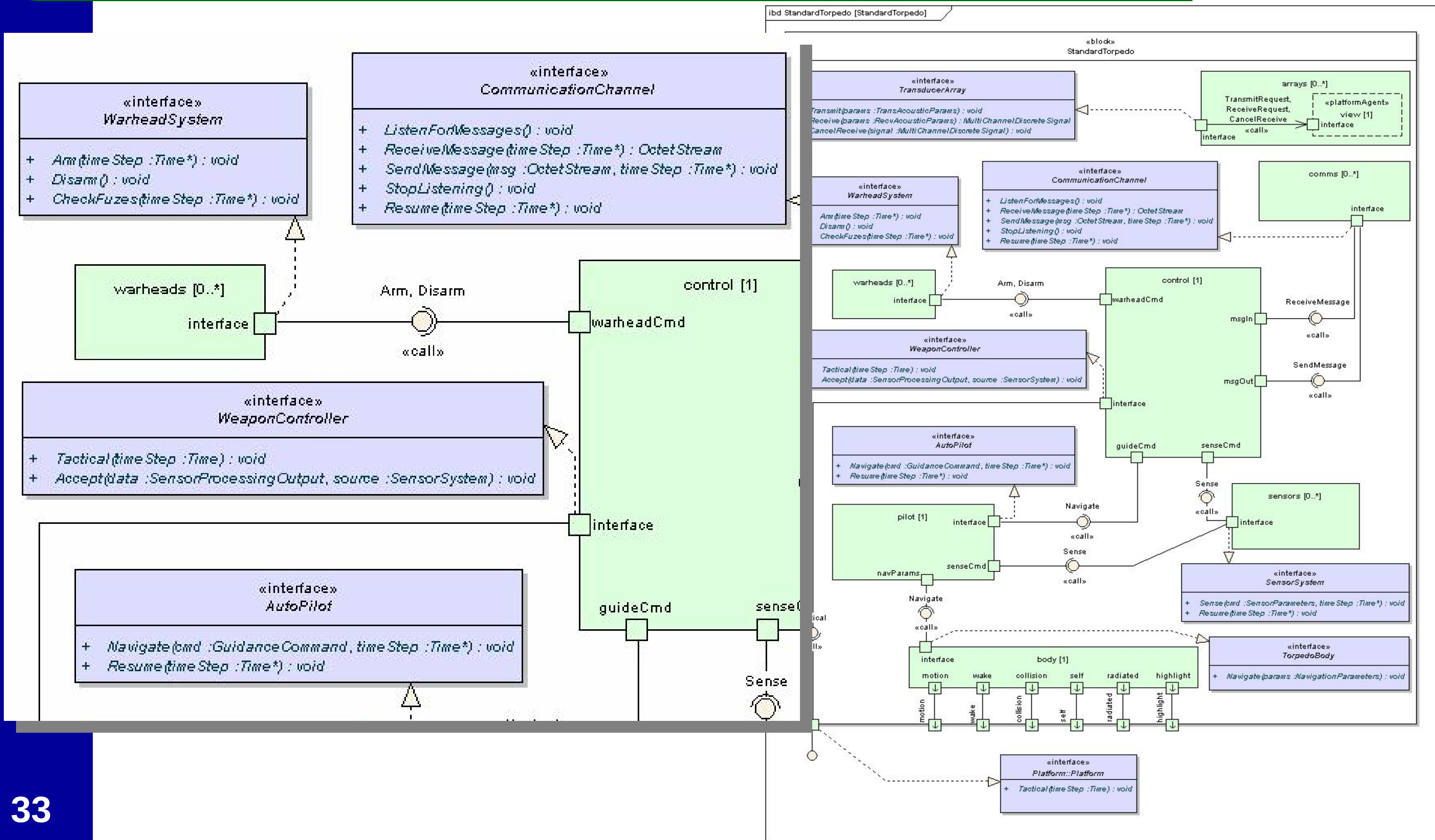
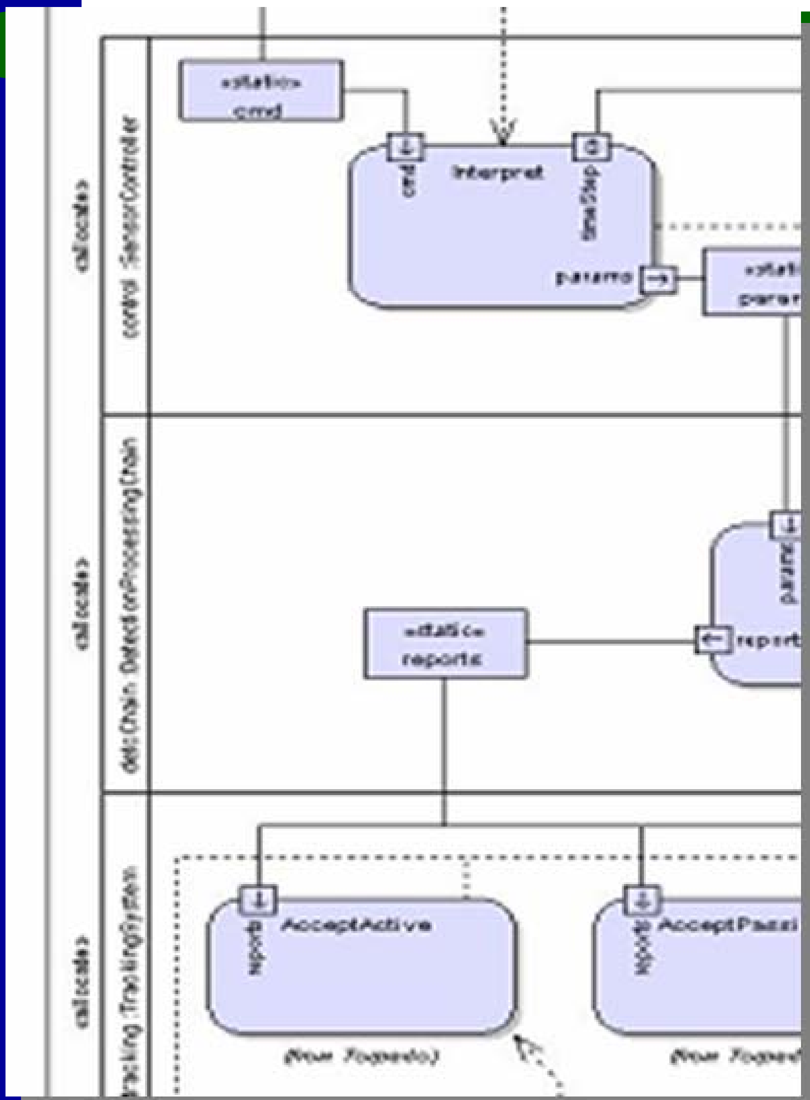
Torpedo Block Definition Diagram

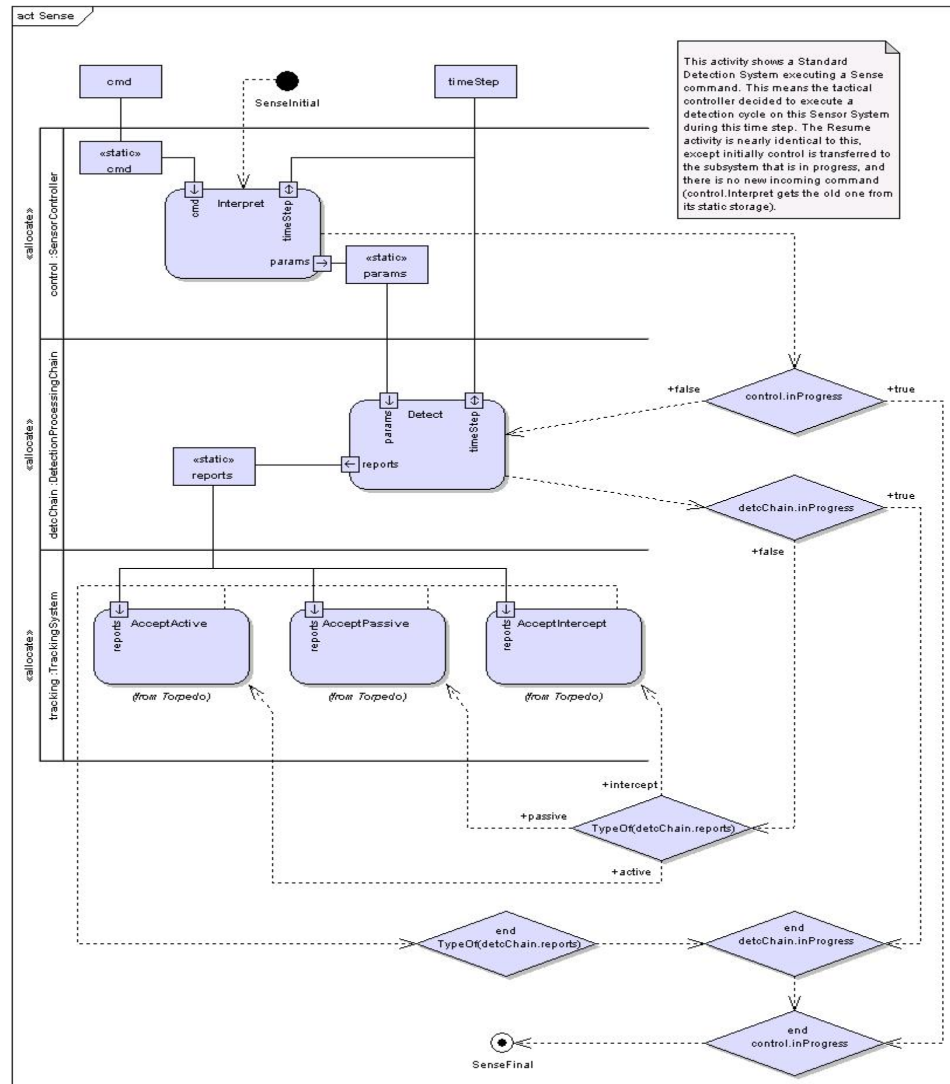


Torpedo Internal
Block Definition Diagram

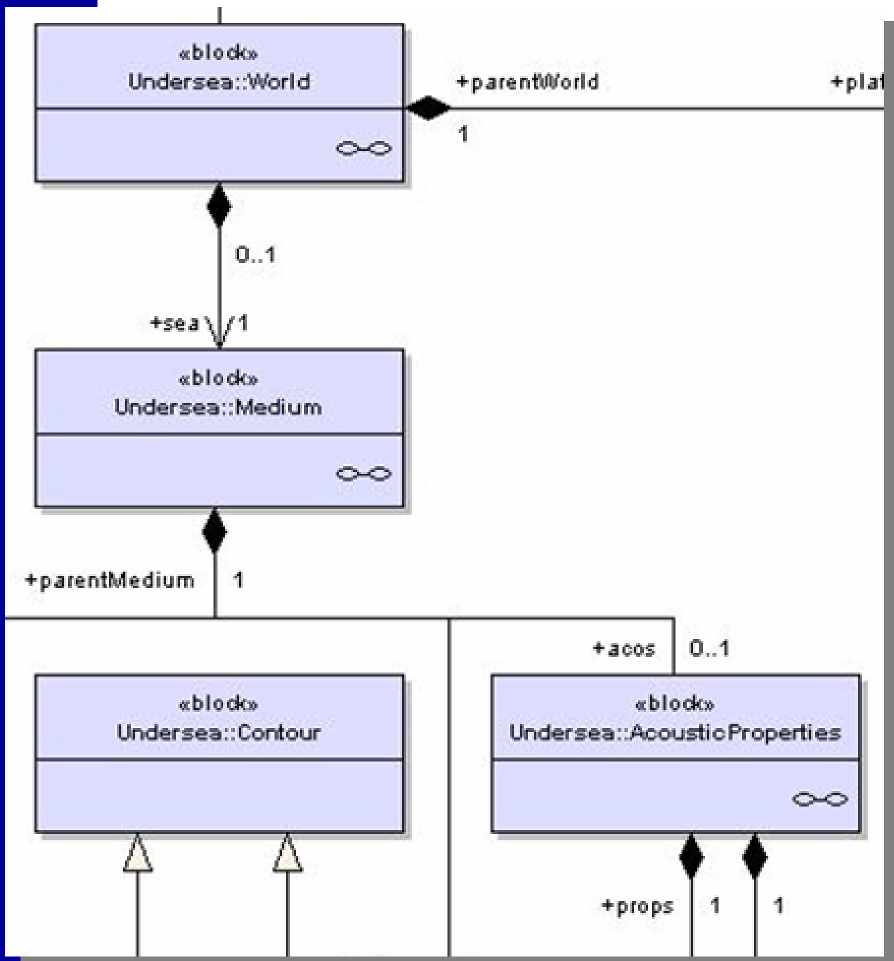


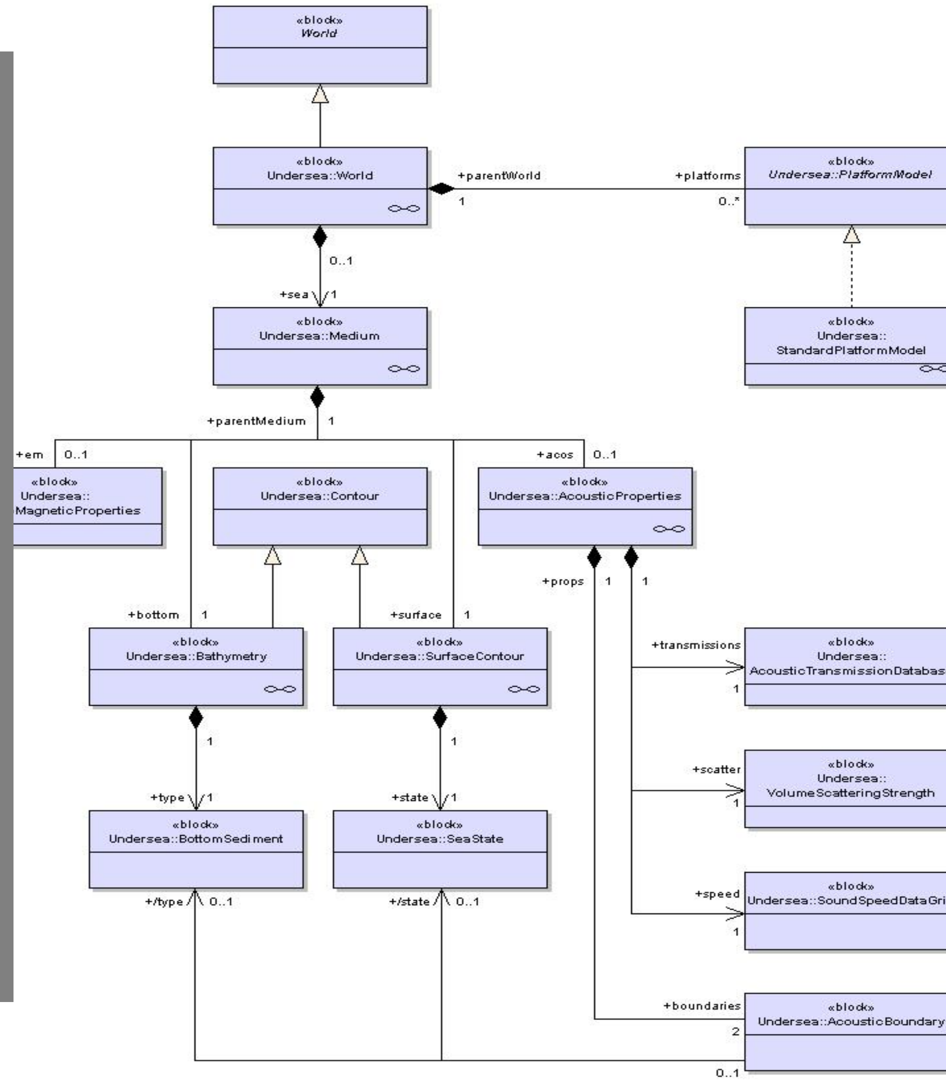
Torpedo Sensor Activity Diagram



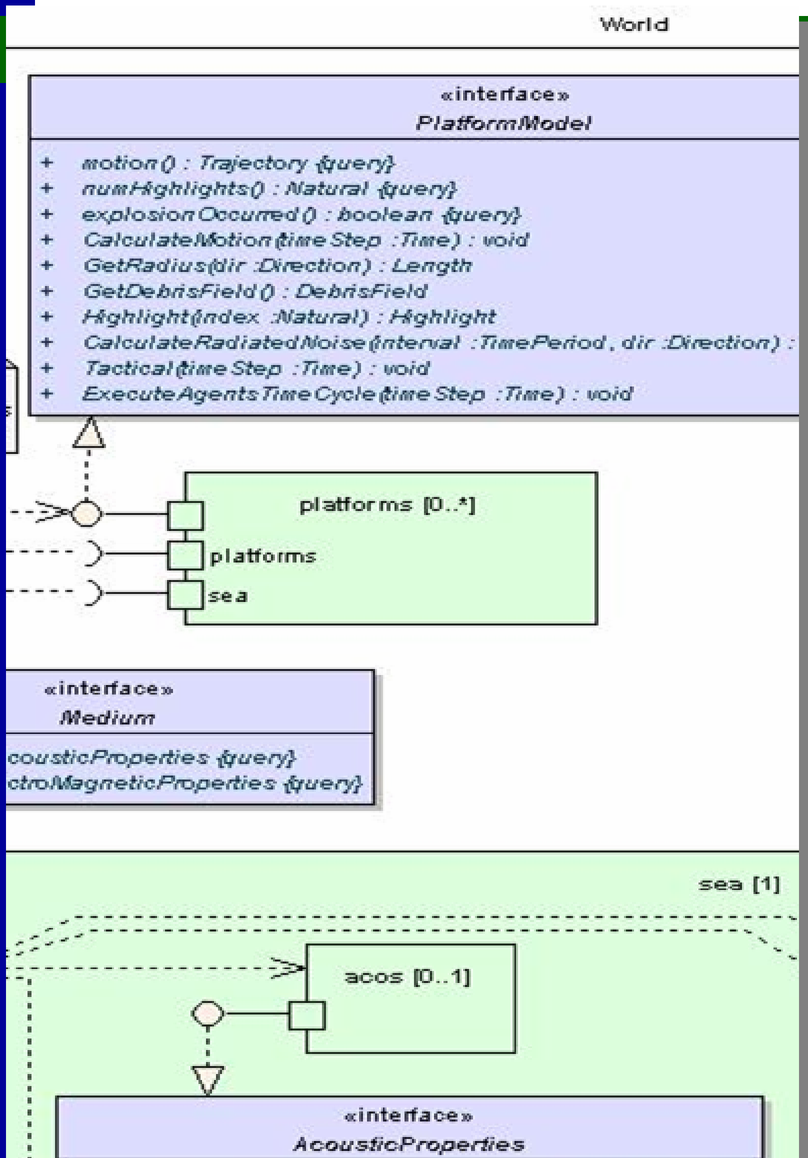


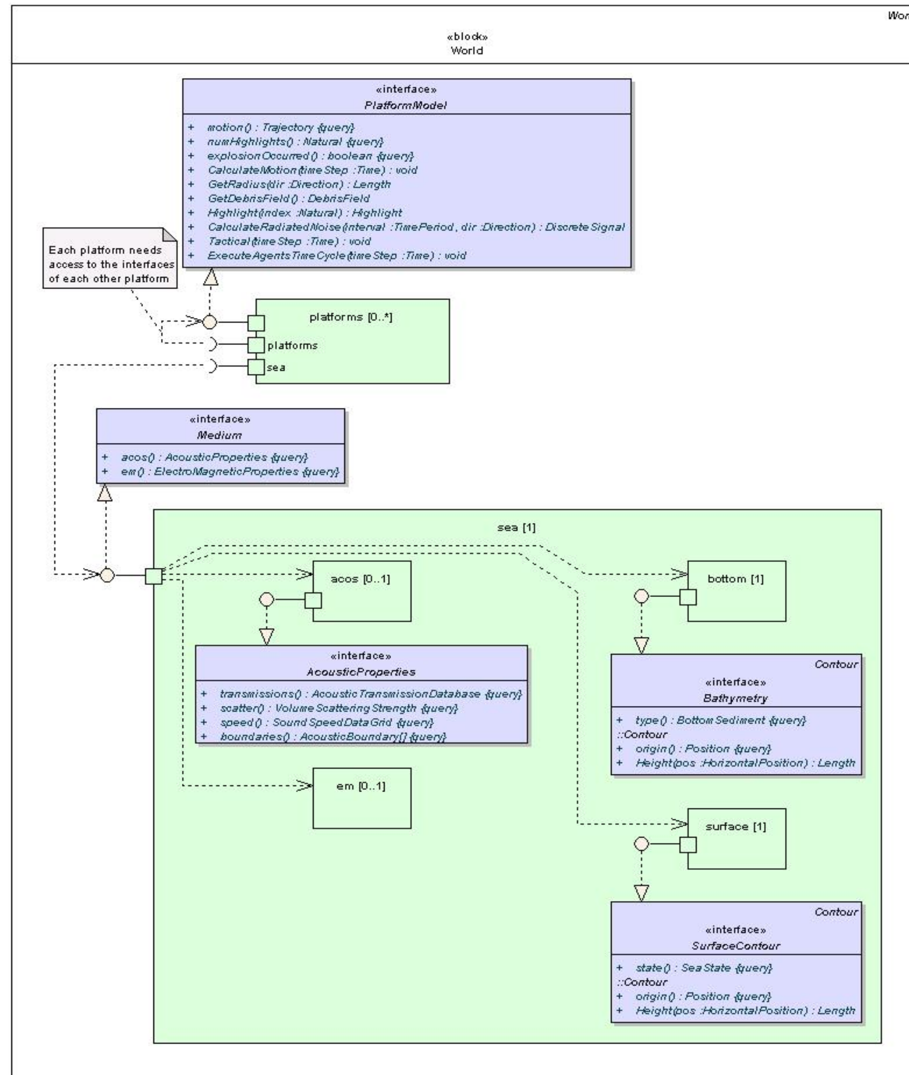
Undersea World
Block Definition Diagram



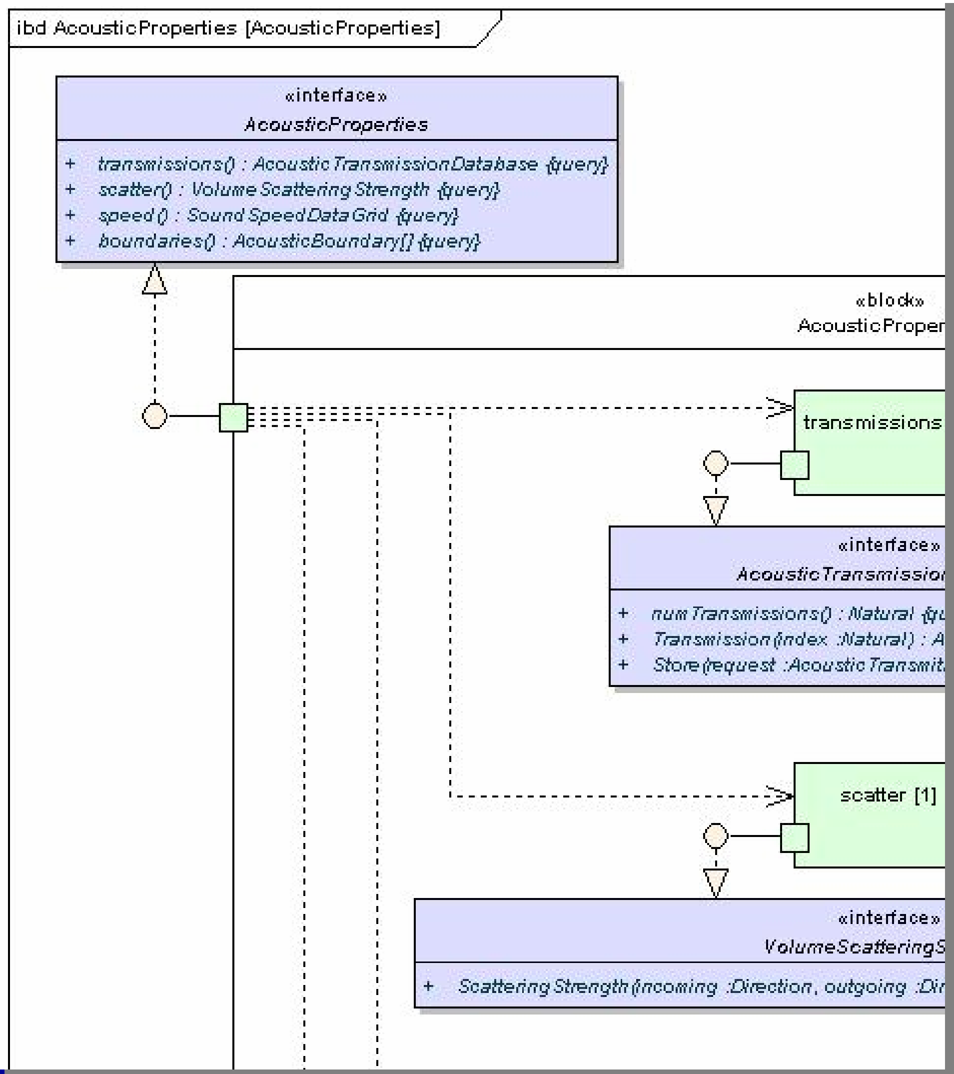


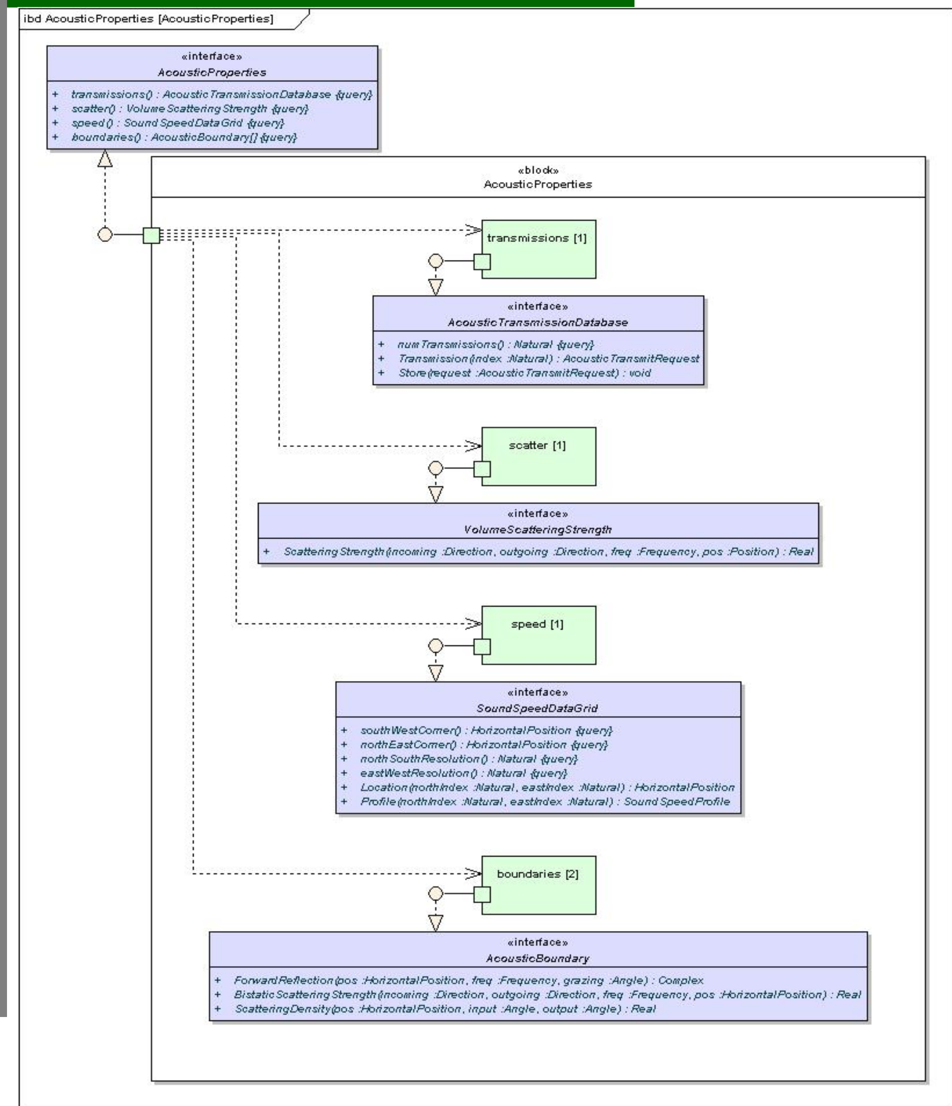
Simulation "World" Internal Block Definition Diagram





Acoustic Properties Internal Block Definition Diagram





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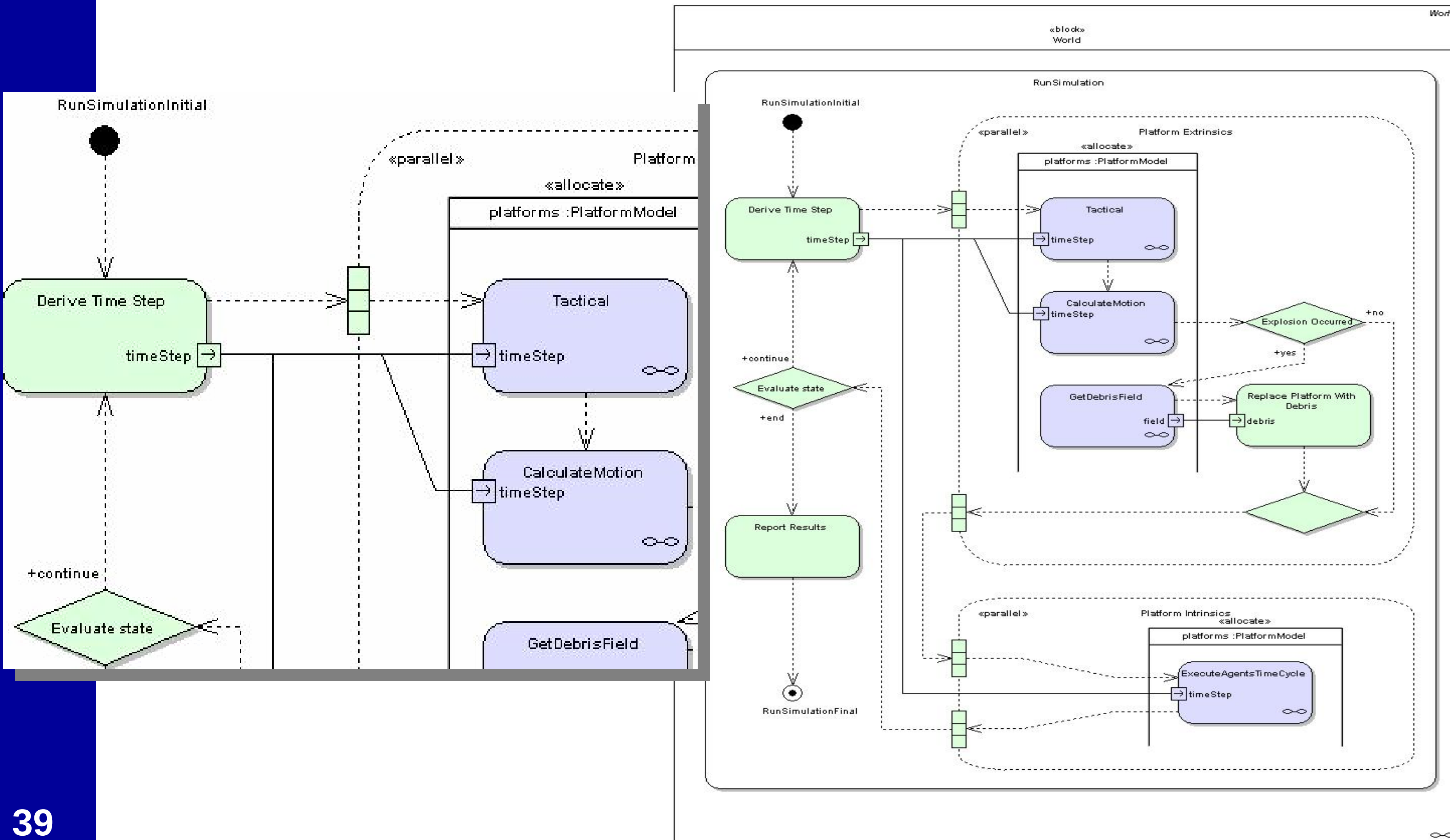
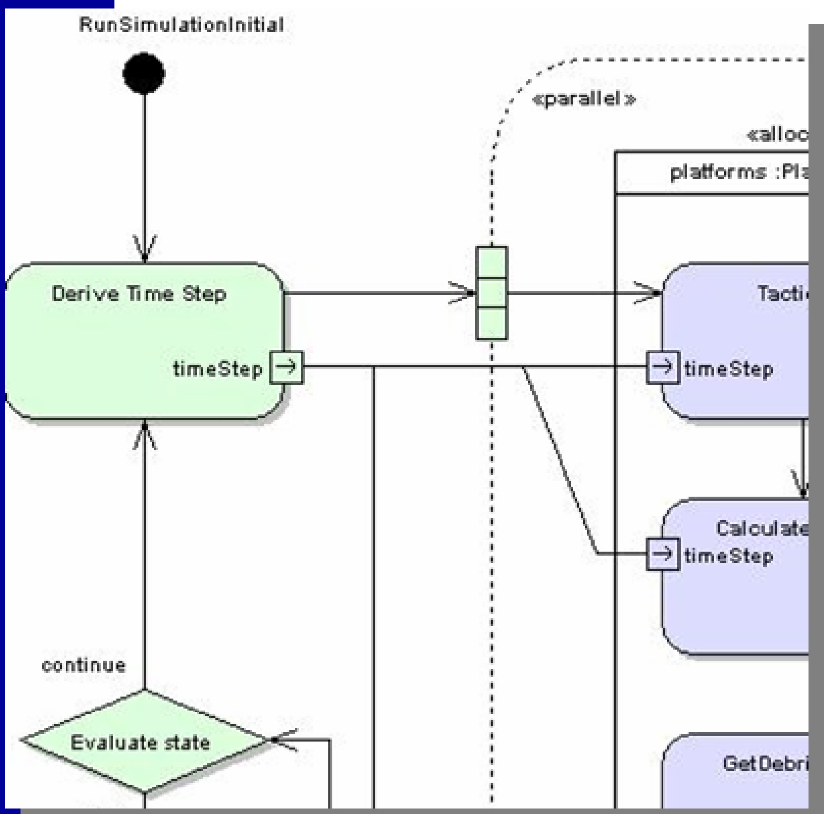
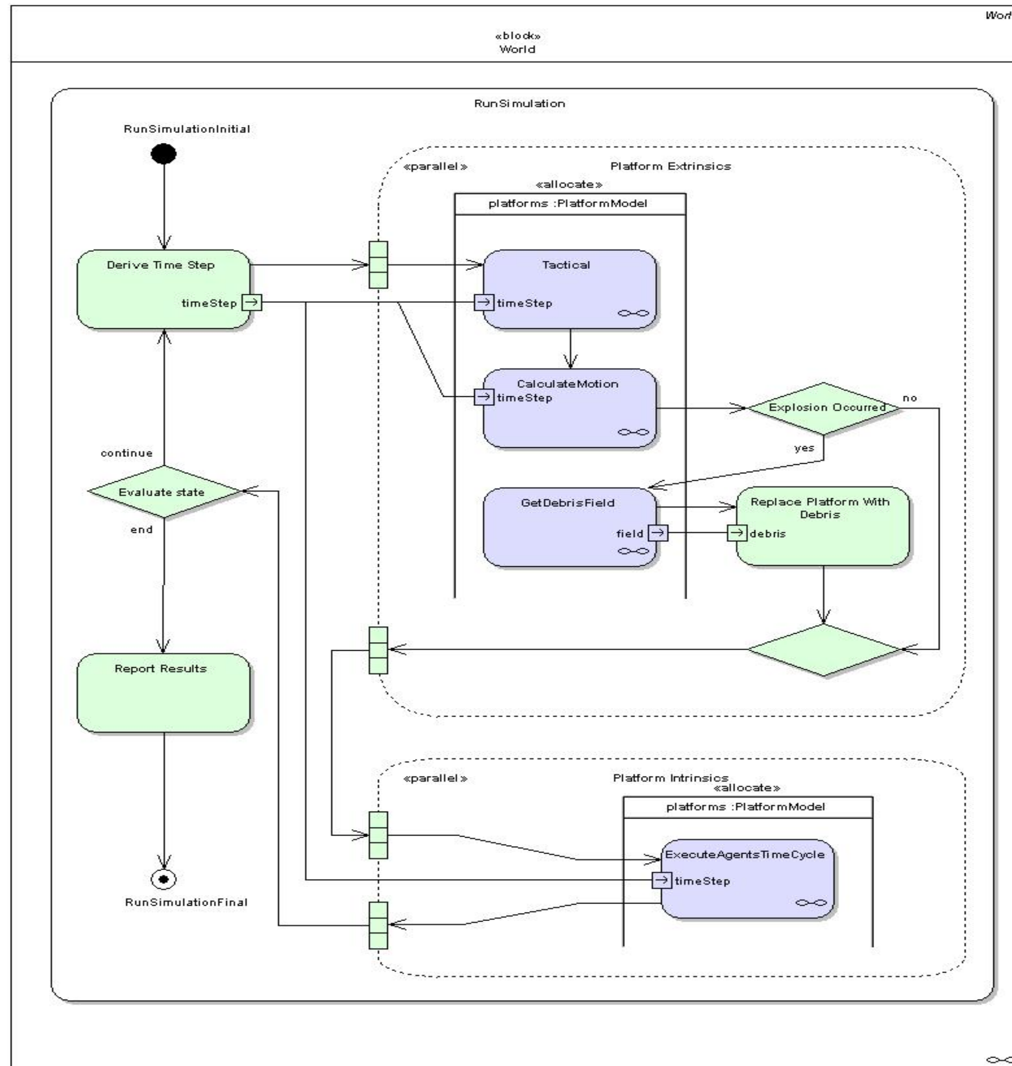


Solid Line Representation





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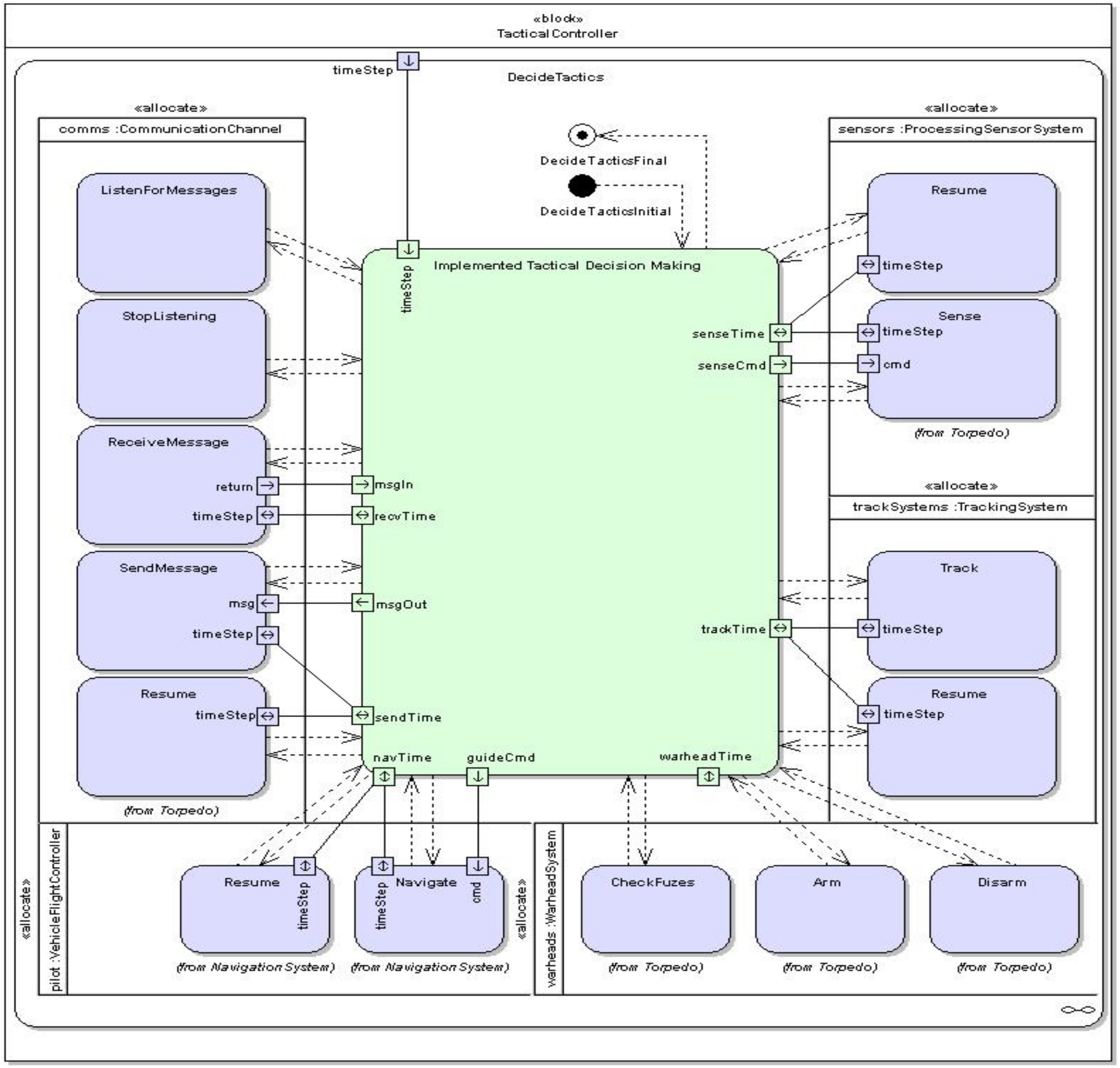
TEAMS
Tactical Controller Example



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Lessons Learned and Value Added

- Requirements traceability is ***vital*** to the success of several TEAMS projects
  - ONR TEAMS standard framework and interfaces
  - OSD-ATL feasibility study
  - TOGAF/MDA Synergy Project
- SysML was designed with "real" systems in mind
  - where UML is software oriented
- Perceived concreteness – simulated vs. actual system
  - not just one way to design interfaces, need recommendations for implementation
- Still need some UML features not present in SysML
  - <<Instantiate>> or <<create>> for dynamic allocation
- Still need guidance on how to best implement parametrics and constraints for modeling and simulation

OMG SE DSIG Recommendation

"Clarify the distinction between the domain model and the simulation design model."

*Reference SE DSIG minutes from OMG San Diego Meeting on March 27, 2007

Integrating SysML Models with Simulation Models

- Goal
  - Integrate system design models with simulation and analysis models
    - Use SysML models to specify an executable architecture
    - Use simulation and analysis models to analyze performance
- How can they work together ?
  - Plug the SysML executable architecture model into a simulation infrastructure to establish a dynamic interface
  - Use the executable architecture model to control the sequence of activities (e.g. detect target, launch weapon)
  - Use the simulation model to compute the parameter values (e.g. missile range to target vs. time)
- What is needed?
  - Approach to use SysML architectural model to specify simulation requirements (use of parametrics?)
  - Harmonization between SysML and simulation standards (i.e. HLA) ?

Source: Sanford Friedenthal, Lockheed Martin, OMG SE DSIG Chair - Recommendation to TEAMS Project

Future Direction

Working to Establish an Activity for SysML / Simulation Integration Approach

- Formulation/establishment during INCOSE MBSE Workshop in Albuquerque on January 24-25
- Liaison to the INCOSE Model Base Systems Engineering (MBSE) Initiative
- Keep abreast of industry related activities
- Help to foster interaction in this area across industry, government and academia to help move towards the INCOSE MBSE Vision.
- Explore this integration through SISO.

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