TOGAF™ ADM/MDA® Synergy Project

Joint Report

A White Paper by The Synergy Project Team

November 2007

This White Paper is an informational document and does not form part of the TOGAF documentation set. Readers should note that this document has not been approved through the formal Open Group Standards Process and does not represent the formal consensus of The Open Group Architecture Forum.

TOGAF™ ADM/MDA® Synergy Project:
Joint Report

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Executive Summary

The purpose of this White Paper is to report on the TOGAF ADM/MDA Synergy Project to the members of its three participating organizations, conveying progress made by the Synergy Project participants and presenting the Synergy Project results and deliverables.

Even though the Synergy Project active participants believe that there could be significantly more work undertaken under the auspices of this project, we have chosen this point in time to develop this "Joint Report". The Synergy Project Team has agreed that, with the publishing of the TOGAF™ ADM/MDA® Synergy Project Integration Proof-of-Concept Results, we have reached a major milestone and agreed that this is a good point to pause our efforts and call a close to this phase of the work.

This Joint Report will also be used to solicit involvement for what could be the "next phase" of this potentially continuing Synergy Project. For the effort to continue, we would expect a major commercial enterprise-level proof-of-concept to be the driving factor. After review of this Joint Report and the above referenced White Paper, we would expect that the clear benefits derived to date would and should entice one or more organizations to step up to the table and offer participation in and help to drive the "next phase".

Introduction

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The Synergy Project did verify the viability of using OMG standards and the tools that implement them in conjunction with TOGAF ADM. The work clearly shows not only the viability of the use together, but also that significant value can be achieved.

Achievements Against Goals

The Synergy Project clearly improved awareness of and verified the viability of using OMG technology (standards and the tools that implement them) in conjunction with TOGAF ADM (methodology).

The Synergy Project provided feedback to the OMG and The Open Group on improvements, gaps, inconsistencies, and errors in MDA specifications and TOGAF ADM. By modeling TOGAF ADM itself, we were able to clearly identify areas of both inconsistency and gaps. This effort has contributed significantly to the development of TOGAF 8.1.1 and provides a good deal of input to the next version of TOGAF. Specifically, feedback from the Synergy Project was helpful in developing the latest version of the Software Process Engineering Metamodel (SPEM 2.0). Suggestions have also been made to OMG in regard to future specifications and demonstrated the need to more clearly articulate which specifications are relevant and orchestrated to develop enterprise architectures. Feedback on the use of tools was also provided.

Although to a lesser degree than we had hoped, the Synergy Project was able to enable architecture practitioners (specifically the TEAMS organization) to see how TOGAF ADM and MDA can be used together to bring greater discipline and re-usability to the field of enterprise architecture. The TEAMS Proof-of-Concept and the resulting case study clearly prove the benefits of the TOGAF framework and MDA specifications working together. Our disappointment is that we did not have a broader set of proofs-of-concept that could show these benefits over a wider number of domains.

[1] White Paper: TOGAF™ ADM/MDA® Synergy Project Integration Proof-of-Concept Results, Doc. No. W073, July 2007, published by The Open Group (refer to www.opengroup.org/bookstore/catalog/w073.htm).

Achievements Against Deliverables

- We identified a set of OMG standards for modeling TOGAF ADM work products and processes. This is in the form of a matrix and can be found in Appendix A: TOGAF ADM/MDA Mapping. We also identified, but didn't necessarily recommend, tools that implement the standards. We did, however, identify the specific tools used both in modeling TOGAF ADM itself as well as those used in the TEAMS Proof-of-Concept.
- We identified and elaborated the business value of the combined TOGAF ADM/MDA approach to enterprise architecture development. This was done, primarily, in the context of the TEAMS Proof-of-Concept. We did achieve hard, measurable values that are elaborated by TEAMS. Also, we suspect that different domains may point out additional values that were not necessarily of importance to TEAMS.
- We provided limited guidelines on how TOGAF practitioners can use the OMG MDA specifications to represent their work products and processes, at this point for TOGAF ADM Phases A through D (due to the focus of the TEAMS effort). Specific OMG specifications were chosen by TEAMS and, where more than one was logically available, we attempt to give the TEAMS rationale for that choice. In the appendices we provide actual models, developed in MDA specifications, of the work products and processes for all ADM phases.

The only pre-declared Synergy Project deliverable that was not achieved to the satisfaction of the Synergy Project Team was the development of guidelines and descriptive best practices offering examples of applying TOGAF methods and procedures to "improve product/service quality from concept to implementation". We feel we have done this, to an anecdotal degree with TEAMS, but this area could certainly be bolstered by broader proof-of-concept participation.

Background

Model Driven Architecture (MDA)

Model Driven Architecture (MDA) is a model-based, standards-based, and tool-supported software engineering approach to developing, manipulating, storing, and sharing precise business-level models of working systems. Based on years of industry practice and research, MDA is an effort led by the Object Management Group (OMG) to develop the software specifications necessary to support model-driven business process and software development. In turn, vendors are developing tools based on these specifications that will make this approach a reality. MDA offers the standards guiding tool development – the "what" – regarding the development of enterprise architectures but does not address the methodology – the "how" – of developing such architectures. An MDA approach is independent of development methodologies as well as technology. This separation of business functionality from computing technology and methodology preserves an organization's core software assets in the constantly changing world of information technology. However, MDA, by design, offers little guidance to the practitioner as that is not its intended purpose. Figure 1 shows the artifacts necessary to transform from computation-independent models to working code.

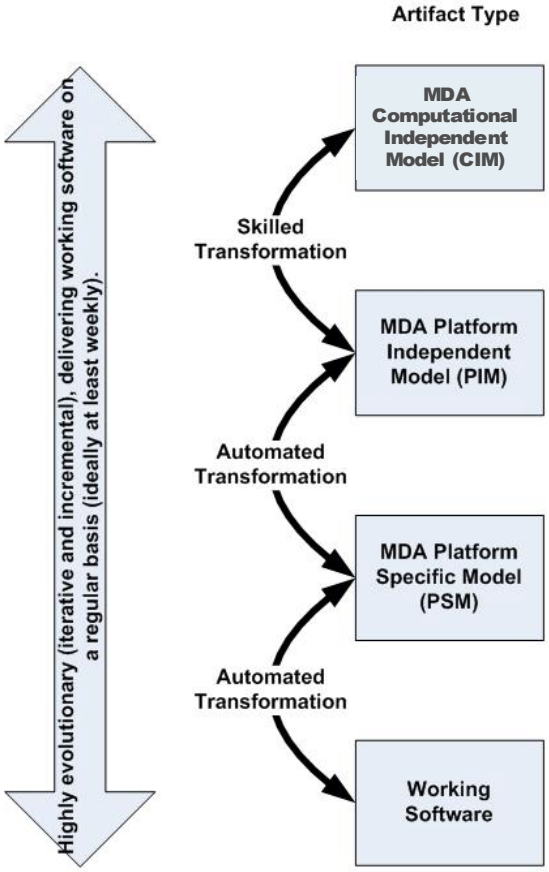

Figure 1: Model Driven Architecture Artifacts

TOGAF and TOGAF ADM

TOGAF is an architecture framework. It provides a method and supporting tools for developing and deploying an enterprise architecture. It is vendor-neutral and was developed through user consensus by The Open Group Architecture Forum. Its intent is to work for any organization, in any industry, and can be adapted to work with any other framework. TOGAF does not mandate any specific tools or modeling standards.

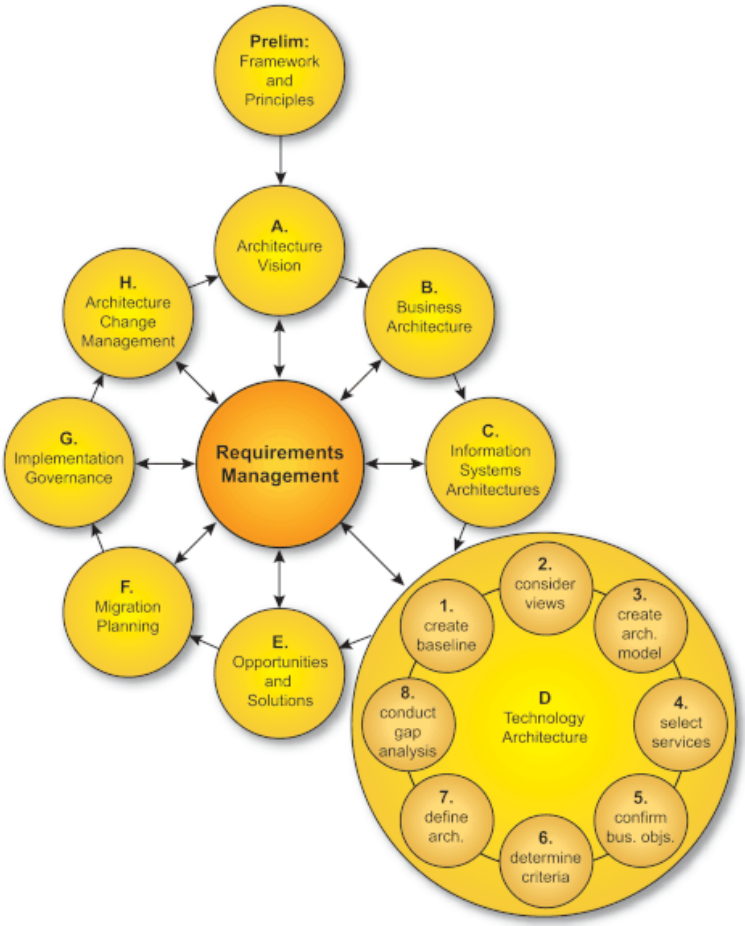

Figure 2: The TOGAF ADM

TOGAF consists of three main parts:

- The Architecture Development Method (ADM) is a process for architecture development and deployment. It is iterative, over the whole process, between phases and within phases. It includes phases covering:
    - — Architecture vision
    - — Architecture descriptions for the business, information systems, and technology domains
    - — Migration planning
    - — Implementation governance
    - — Architecture change management

- The Enterprise Continuum provides a "virtual repository" of re-usable architecture assets. It is further sub-divided into the Architecture Continuum and the Solutions Continuum. It includes:
    - The TOGAF Foundation Architecture, a generic architecture from which an organization-specific architecture can be derived; the Foundation Architecture includes the TOGAF Technical Reference Model (TRM) and the Standards Information Base (SIB)
    - The Integrated Information Infrastructure Reference Model (III-RM)

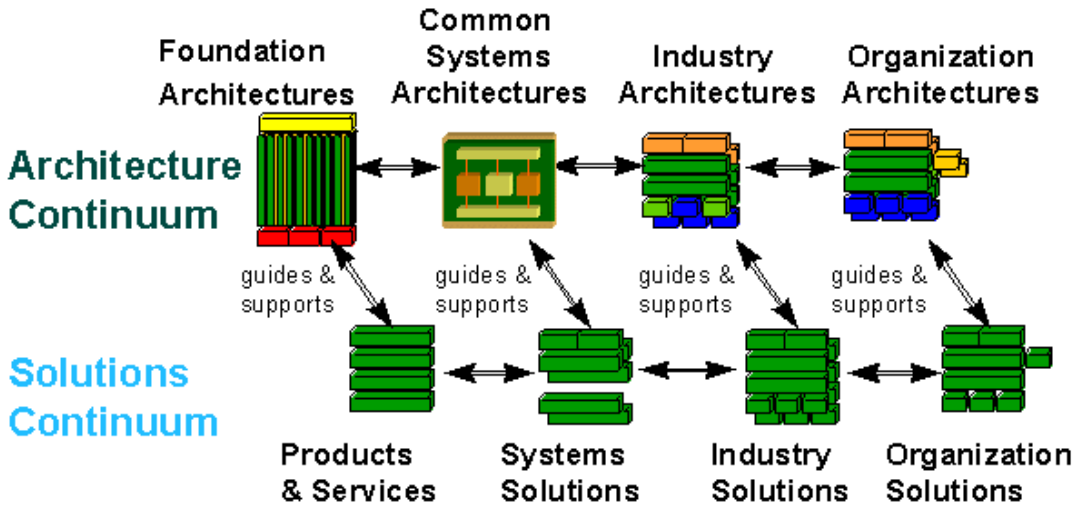

Figure 3: The Enterprise Continuum

- The TOGAF Resource Base provides useful information drawn from the experience of members of the Architecture Forum, to help the architect in the use of the ADM. Topics include:
    - Architecture Board
    - Architecture Contracts
    - Architecture Description Language
    - Architecture Governance
    - Architecture Maturity Models
    - Architecture Patterns
    - Architecture Principles
    - Architecture Reference Models and comparisons
    - Architecture Skills Framework
    - Architecture Tools
    - Architecture Views
    - Business Scenarios
    - Case Studies

— IT Governance

— Other Architecture Frameworks

The Synergy Project

Recognizing that both of these industry technologies are complementary, a paper (see ADM & MDA in References) was published in 2004 seeking to describe and promulgate the enormous synergy that exists within the industry if these concepts are used effectively together. Born from that paper was the TOGAF ADM/MDA Synergy Project, originally composed of members of the Object Management Group and The Open Group and later joined by the Integration Consortium.

Three organizations played a critical role in the development of this Synergy Project and supported us in attaining our goals and deliverables. They have been mentioned throughout this report. Without their active support, and active participation by their members and staff, we would never have reached this point of accomplishment.

The Open Group is a vendor-neutral and technology-neutral consortium, which drives the creation of Boundaryless Information Flow™ that will enable access to integrated information within and between enterprises based on open standards and global interoperability. The Open Group works with customers, suppliers, consortia, and other standard bodies to capture, understand, and address current and emerging requirements, establish policies and share best practices; to facilitate interoperability, develop consensus, and evolve and integrate specifications and open source technologies; to offer a comprehensive set of services to enhance the operational efficiency of consortia; and to operate the industry's premier certification service.

The Open Group is organized by Forums and Working Groups. The specific responsibility for The Open Group contribution to this work has been the Architecture Forum. The Architecture Forum has developed and is evolving TOGAF to enable businesses to achieve the right balance between IT efficiency and business innovation, while also taking into consideration the constantly changing needs of the business environment. A certification program supports TOGAF.

The **Object Management Group (OMG)** is an international, open membership, not-for-profit computer industry consortium headquartered in Needham, MA, USA. OMG members develop enterprise integration standards for a wide range of technologies, including: Real-time, Embedded, & Specialized Systems, Analysis & Design, Business Modeling & Integration, Architecture-Driven Modernization & Middleware, and an even wider range of industries, including: C4I, Finance, Government, Healthcare, Legal Compliance, Life Sciences Research, Manufacturing Technology, Robotics, Software-Based Communications, and Space.

OMG's modeling standards, including the Unified Modeling Language (UML) and Model Driven Architecture (MDA), enable powerful visual design, execution, and maintenance of software and other processes, including IT Systems Modeling, Business Process Management, and support of the Service-Oriented Architecture approach to providing business services. OMG's middleware standards and profiles are based on the Common Object Request Broker Architecture (CORBA) and support a wide variety of industries.

The **Integration Consortium (IC)** is a non-profit, leading industry body responsible for influencing the direction of the integration industry. Its members champion Integration Acumen by establishing standards, guidelines, best practices, research, and the articulation of strategic and measurable business benefits. The Integration Consortium's motto is "Forging Integration Value". The mission of the member-driven Integration Consortium is to establish universal seamless integration that engages industry stakeholders from the business and technology community. Among the sectors represented in the Integration Consortium

membership are end-user corporations, independent software vendors (ISVs), hardware vendors, system integrators, academic institutions, non-profit institutions, and individual members as well as various industry leaders.

Project Technical and Business Value

Given the background of the original OMG and Open Group members of the Synergy Project, the expected value of the project was quickly assessed from a technical viewpoint.

In summary, the technical value was assessed as follows:

- Provides a single source point for technology and processes related to developing enterprise architectures.
    - Recognizing that both technologies draw upon years of experience within other organizations and industry activities, this effort will take a broad view of applicability.
- Enables architecture practitioners to select the elements of TOGAF and MDA that will provide a disciplined approach to the development of architectures and systems that are tailored to the specific business needs of the organization.
- Provides clearly defined, industry-wide roles and accountability for the effective creation of architectures and systems.
- Promotes a higher degree of transparency that will improve the communications and understanding between the architecture, development, and operations personnel.
- Enhances the portability, re-usability, and interoperability of enterprise architectures and system architectures to facilitate the efficient and effective integration of enterprise applications.

With the addition of the Integration Consortium to the team, a strong case was made for identifying the business value of the effort in recognition that it would contribute as much to the success of the Synergy Project as proof of technical merit. To that purpose, the team continued to refine its view of the value of combining TOGAF ADM with MDA in developing enterprise architecture. By articulating business value, the following is achieved:

- Providing a coordinated, disciplined approach to developing and implementing standards-based enterprise architectures and systems that are focused on meeting business needs.
- Providing a clear and unambiguous (yet customizable) process for:
    - Creating enterprise architectures and their related detailed architectures and system design
    - Creating higher-quality and lower-cost deliverables
    - Re-use of architecture
    - Standards-based traceability from the operations level back to the architecture
- Providing opportunities for tools vendors to create products that leverage a proven chain of methods and standards without having to cover the whole span from business rationale to running code.
- Promoting greater collaboration among consultancies and system integrators and their subcontractors in managing large, complex projects through leveraging well articulated methods and guidelines.

Project Goals

The goals of the Synergy Project identified were threefold:

1. To verify the viability of using OMG technology (standards and the tools that implement them) in conjunction with TOGAF ADM (methodology).
2. To provide feedback to the OMG and The Open Group on improvements, gaps, inconsistencies, and errors in MDA specifications and TOGAF ADM.
3. To enable architecture practitioners to see how TOGAF ADM and MDA can be used together to bring greater discipline and re-usability to the field of enterprise architecture.

Project Deliverables

The Synergy Project deliverables identified were designed to meet the goals stated above. These deliverables include:

1. A list of OMG standards for modeling TOGAF ADM work products and processes and identification of tools implementing them.
2. Identification and elaboration of the business value of the combined TOGAF ADM/MDA approach to enterprise architecture development.

   Recognizing that identifying business value will contribute as much to the success of the Synergy Project as proof of technical merit, the team planned to refine its view of the business value of combining TOGAF ADM with MDA in developing enterprise architecture. It is expected that, by articulating business value, the following would be achieved:

   — Providing a coordinated, disciplined approach to developing and implementing standards-based enterprise architectures and systems that are focused on meeting business needs.

   — Providing a clear and unambiguous process for:

   — Creating enterprise architectures and their related detailed architectures and system design

   — Creating higher-quality and lower-cost deliverables

   — Re-use of architecture

   — Standards-based traceability from the operations level back to the architecture

   — Providing opportunities for tools vendors to create products that leverage a proven chain of methods and standards without having to cover the whole span from business rationale to running code.

   — Promoting greater collaboration among consultancies and system integrators and their subcontractors in managing large, complex projects through leveraging well articulated methods and guidelines.
3. Guidelines and descriptive business best practices offering examples of applying TOGAF methods and procedures to improved product/service quality from concept to implementation.
4. Guidelines on how TOGAF practitioners can use the metamodels and profiles based on OMG specifications to represent their work products.

5. Assessment of applying an MDA modeling approach to TOGAF work products and processes; for example, answering questions such as: are all ADM building blocks modeled the same way?

Project Approach

The original intent was to develop a proof-of-concept based on some clear TOGAF ADM user case study. TOGAF ADM was the starting point, and from there the concept was to model the appropriate TOGAF Phase work products and activities in OMG specifications.

Although this sounds fairly straight forward, we found that it was more complex than originally envisioned. It was complicated in two major dimensions:

1. It turns out that there was not a direct one-to-one mapping of the TOGAF work products to the OMG specifications and, in fact, many of the work products could potentially be mapped to multiple OMG specifications. As a result, we determined that we needed some sort of coherent mapping document that took each of the work products and identified the potential OMG specifications that could be used and then assist TEAMS in choosing the "best" OMG specification for TEAMS purposes.

2. The second dimension was even more complex. In attempting to determine just what work products TOGAF ADM called for, we found problems of lack of specificity, inconsistent taxonomy, and minor errors as to just what specific areas of the document meant. The Synergy Project Team then determined that developing a model of TOGAF ADM itself might help resolve some of these questions. And, we determined that modeling TOGAF ADM could prove to be valuable input to the TOGAF development team as TOGAF moves forward.

Project Execution

In support of the of the project approach, we had two modeling efforts underway simultaneously, each supporting the other: the TEAMS Proof-of-Concept and modeling activities of the Synergy Project's Modeling Team. Below are detailed descriptions of these modeling efforts.

TEAMS Proof-of-Concept

Several organizations had a long history of developing and continuing to evolve modeling and simulation tools for the Navy that are used to develop systems and evaluate system performance in a variety of business and technical scenarios. While these organizations developed comparable tools with similar components to satisfy their sponsors' modeling and simulation needs, there was very little communication between them as to what tools were available, and under which conditions they were best applicable. Additionally, several components with similar functionality but varying fidelity were developed in parallel, with no forethought of how to integrate a lower fidelity version with a higher fidelity representation if a sponsor were to desire more realism in a system simulation.

Sponsors realized the business model for funding modeling and simulation development needed to change. Funding dollars were not available to support multiple yet similar models developed by several organizations. Sponsors had the desire to leverage what was already developed under previous programs, but did not have a framework in place to easily encourage organizations to share information.

To address this, the Office of Naval Research established the Torpedo Enterprise Advance Modeling and Simulation (TEAMS) program to open the lines of communication among the Navy's modeling and simulation communities, and to standardize how models from multiple development teams could be integrated into one or more simulation tools. Two organizations – the Applied Research Laboratory of the

Pennsylvania State University (ARL/PSU) and the Naval Undersea Warfare Center, Division Newport (NUWCDIVNPT) – were tasked to establish an Undersea Warfare (USW) M&S Consortium. The Consortium purpose was to define and develop a cross-enterprise, collaborative undersea warfare modeling and simulation environment utilizing re-usable components that can be composed into highly integrated simulations. This simulation environment was to be driven by an open systems architecture framework that would result in the sharing and leveraging of both legacy and new development resources. It is intended to support both the development of modeling and simulation tools and the application of these tools across the lifecycle of undersea weapons.

TEAMS and TOGAF

Because NUWCDIVNPT and ARL/PSU did not have experience developing a collaborative working environment among multiple organizations, they investigated the existence of other consortia to possibly leverage lessons learned. Their search brought them to The Open Group. The Open Group established and maintains a leading international consortium for information technology, and also offers consortia services to enable others to establish their own. They also have extensive experience working with customers to capture, understand, and address current and emerging requirements, establish policies, and share best practices. They have worked with vendors, consortia, and standards bodies to develop consensus and facilitate interoperability, to evolve and integrate open specifications and open source technologies.

In the process of learning about consortium management, NUWCDIVNPT and ARL/PSU learned about The Open Group Architecture Framework (TOGAF) and the Architecture Development Methodology (ADM). They quickly realized that this process was essential to achieving the architecture goals of the TEAMS program.

Figure 4 shows several modeling and simulation tools available to the Navy. The TEAMS Consortium used these as their baseline technology architecture, and planned to leverage components from each to achieve a common architecture framework. This task was their starting point for TOGAF architecture development work.

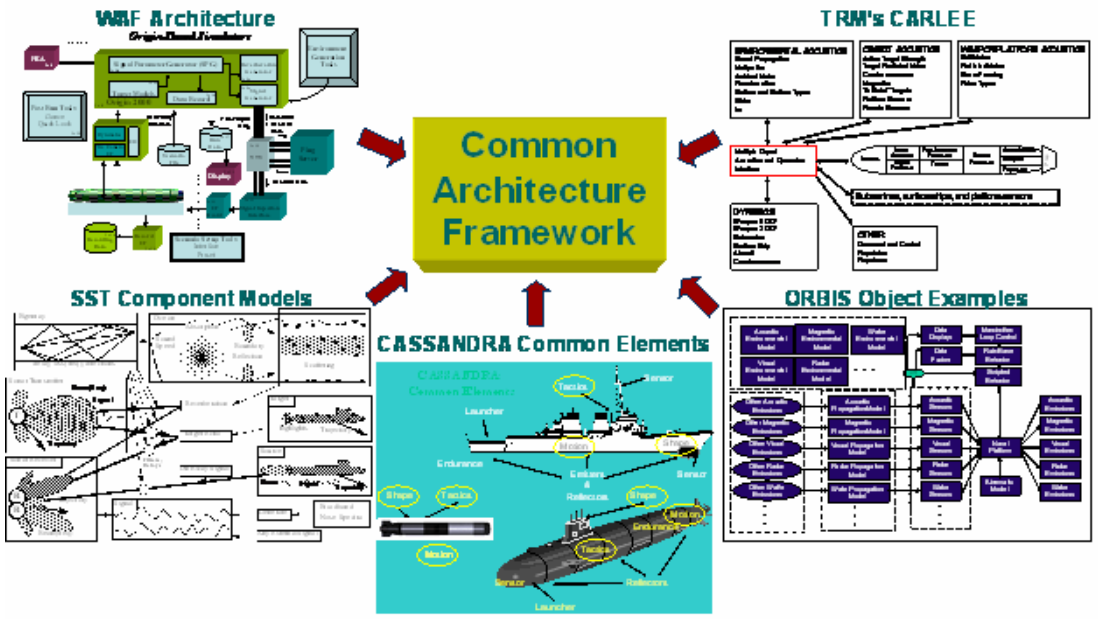

Figure 4: TEAMS Baseline Technology Architecture

TEAMS and MDA

The TEAMS Consortium used TOGAF ADM as a guideline for developing a conceptual model, taxonomy structure, and standard interfaces for models used by the torpedo modeling community. This provided the "how" which TEAMS needed to frame their problem and potential solutions. But they were still missing the "what" to provide the specific representation of the artifacts needed to represent the architecture. TEAMS was dealing with a situation where the concept of "separation of concerns" was immediately evident. There were several specific torpedoes (the fired platforms) that needed to be considered. However, the acoustic environment could be identical for each of the torpedo platforms. This led TEAMS to the OMG and the "separation of concerns" concepts inherent in Model Driven Architecture (MDA). TEAMS realized that MDA provided an ideal mechanism to map between conceptual models, platform-independent models, platform-specific interface implementations, and working code.

The OMG Unified Modeling Language (UML), Software Process Engineering Metamodel (SPEM), and System Modeling Language (SysML) modeling specifications enabled TEAMS to capture detailed descriptions of static and dynamic class relationships, interface requirements, key data types, and components needed to create a standardized undersea weapon engagement simulation framework. This has facilitated TEAMS developing and integrating re-usable components of different acoustic models, torpedo models, and simulations.

At first, TEAMS' primary focus was to only represent their technology architecture using MDA. They used TOGAF to discuss business processes and strategic drivers, but never formally captured the information other than in text. After becoming involved in the TOGAF/MDA Synergy Project, they quickly realized that several OMG specifications for business models would be invaluable for tracing business requirements through technology description to final software deployment. The mapping of TEAMS-specific TOGAF work products (those only relevant to TEAMS) from Phases A through D represented as elements of OMG specifications such as UML, SysML, and Business Motivation Model (BMM) are provided in Appendix A through D.

Synergy Project Modeling Team

The Synergy Project Modeling Team built a formal process model of TOGAF 8.1 ADM following ADM practice and using the Software Process Engineering Metamodel (SPEM) Version 1.1, an OMG specification for capturing development methods and processes. This process model is the foundation of many of the Synergy Project's fundamental objectives including:

- To map every ADM work product (modeled in the SPEM process model) to one or many OMG specifications (and very precisely to specific elements with each specification).
- To demonstrate the viability of using MDA specifications (such as UML, SPEM, BMM, BPMN, BPDM, etc.) to describe The Open Group industry standard approaches to enterprise architecture development (i.e., TOGAF and ADM).
- To identify errors, inconsistencies, and gaps in TOGAF 8.1 and opportunities for improvement in future versions of TOGAF.

While all three objectives are critical to all participating Synergy Project member organizations, the second one is perhaps the most immediately relevant to each organization's practitioner membership. People applying TOGAF on enterprise architecture projects in the real world want to know:

- "Is there an industry standard specification for the work product I'm trying to produce?"
- "If so, which specification and which piece of the specification?"

- "Which tools implement the specification (so I know where to put the work product and in what form)?"
- "If this work product changes, what ADM activities might we need to revisit (because the work product is used as an input to other activities)?"
- "What is the relationship between this work product and other ADM work products?"

By using a proven process metamodel (SPEM) to capture TOGAF ADM, practitioners gain additional benefits:

- Leverage industry standards and best practices on process modeling.
- Provide a foundation for ongoing, managed evolution of TOGAF ADM method content.
- Provide the basis for ADM process enactment and management with tools (that implement SPEM).
- Use standard-based XMI as formal data storage for TOGAF assets.
- Ability to integrate ADM with other processes (OpenUP, CoBIT, ITIL, CMMI, PMBOK, etc.) also described with SPEM models.

One final benefit of the mapping is the opportunity to identify gaps and redundancies in the MDA family of OMG specifications and suggest areas for future improvement.

Report of Project Completion

Project Summary

Achievements against Goals

1. Verify the viability of using OMG technology (standards and the tools that implement them) in conjunction with TOGAF ADM (methodology).

The Synergy Project did verify the viability of using OMG standards and the tools that implement them in conjunction with TOGAF ADM in the development of enterprise architectures. The work clearly shows not only the viability of their use together, but also that significant value can be achieved.

Going through the exercise of mapping TOGAF ADM work products to elements of OMG specifications was invaluable to TEAMS. The project team gained insight into their requirements, which they were able to formally capture and articulate to stakeholders with multiple views. They also could provide complete requirements traceability from their architecture vision, business processes, and data and applications architectures down to the technology architecture that was developed to demonstrate component interoperability for the torpedo modeling and simulation community.

2. Provide feedback to the OMG and The Open Group on improvements, gaps, inconsistencies, and errors in MDA specifications and TOGAF ADM.

The Synergy Project did provide feedback to the OMG and The Open Group on improvements, gaps, inconsistencies, and errors in MDA specifications and TOGAF ADM. By modeling TOGAF ADM itself, we were able to clearly identify areas of both inconsistency and gaps. This effort has contributed significantly to the development of TOGAF 8.1.1 and provides a good deal of input to the next version of TOGAF. The project clearly improved the awareness of and validated the use of MDA specifications in the development of enterprise architecture. Specifically, feedback from the project was helpful in developing the latest version of the Software Process Engineering Metamodel (SPEM 2.0). Suggestions have also been made to OMG in regard to future specifications and demonstrated the need to more clearly articulate which specifications are relevant and orchestrated to develop enterprise architectures. For instance, a recommendation has been made to add a UML Profile for the Business Motivation Model (BMM) to OMG's roadmap for Business Process Modeling specifications. Feedback on the use of tools was also provided.

The Synergy Project Modeling Team made a number of recommendations to the The Open Group Architecture Forum on improvements to TOGAF 8.1, which resulted in TOGAF 8.1.1. These recommendations were reported to the Architecture Forum via its standard enhancement request system and incorporated into TOGAF using its standard update process. The types of items included:

- Use active verb noun phrases for the steps described within each phase. For example, in the Architecture Vision phase, the steps "Project Establishment" and "Statement of Architecture Work and Approval" were changed to "Establish the Project" and "Develop Statement of Work and Secure Approval".
- Clarify ambiguous or inconsistent identification of the inputs and outputs of each phase. For example, in TOGAF 8.1, one of the outputs of the Business Architecture phase "Business Baseline – Version 2" was renamed to "Baseline Business Architecture, Version 1.0" in TOGAF 8.1.1.
- Clarify incomplete or inconsistent relationships among work products. For example, in TOGAF 8.1, one of the output work products of the Architecture Vision phase is identified as "Business Scenario", which

is described as being composed of four work products: "Business Baseline Version 1", "Technical Baseline Version 1", "Business Architecture Version 1", and "Technical Architecture Version 1". In TOGAF 8.1.1 these work products are described as composite elements of "Architecture Vision" ("Business Scenario" was determined to be a technique, not an actual work product), renamed, and expanded to include additional architecture descriptions. Now the Architecture Vision is composed of "Baseline Business Architecture, Version 0.1", "Baseline Technology Architecture, Version 0.1", "Baseline Data Architecture, Version 0.1", "Baseline Applications Architecture, Version 0.1", "Target Business Architecture, Version 0.1", "Target Technology Architecture, Version 0.1", "Target Data Architecture, Version 0.1", and "Target Applications Architecture, Version 0.1".

3. Enable architecture practitioners to see how TOGAF ADM and MDA can be used together to bring greater discipline and re-usability to the field of enterprise architecture.

Although to a lesser degree than we had hoped, the Synergy Project was able to enable architecture practitioners (specifically the TEAMS organization) to see how TOGAF ADM and MDA can be used together to bring greater discipline and re-usability to the field of enterprise architecture. The TEAMS Proof-of-Concept and the resulting case study clearly prove the benefits of the TOGAF framework and MDA specifications working together. Our disappointment is that we did not have a broader set of proofs-of-concept that could show these benefits over a wider number of domains.

By extension, it is also important to provide architecture practitioners with an articulation of technical benefits:

- Leverage industry standards and best practices on process modeling
- Provide a foundation for ongoing, managed evolution of TOGAF ADM method content
- Provide the basis for ADM process enactment and management with tools (that implement SPEM)
- Use standard-based XMI as formal data storage for TOGAF assets
- Ability to integrate ADM with other processes (OpenUP, CoBIT, ITIL, CMMI, PMBOK, etc.)

Achievements against Deliverables

1. A list of OMG standards for modeling TOGAF ADM work products and processes and identification of tools implementing them.

We have delivered a recommended set of OMG standards for modeling TOGAF ADM work products and processes. This is in the form of a matrix and can be found in Appendix A: TOGAF ADM/MDA Mapping. We do identify, but don't necessarily recommend, tools that implement the standards. We do, however, identify the specific tools used both in modeling TOGAF ADM itself as well as those used in the TEAMS Proof-of-Concept.

While the project identified relevant MDA specifications, a need for greater integration among OMG specifications when developing enterprise architectures was recognized. While no tool recommendations were made, the project added further validation of the viability of using tools implementing OMG specifications in the development of enterprise architectures.

2. Identification and elaboration of the business value of the combined TOGAF ADM/MDA approach to enterprise architecture development.

The identification and elaboration of the business value was achieved primarily in the context of the TEAMS Proof-of-Concept. By using TOGAF ADM to capture architecture vision, principles, and requirements, and

using OMG specifications to formalize TOGAF's business processes, data, and applications architecture work products, TEAMS has shown how these technologies can produce a roadmap for developing a modeling and simulation technology architecture. As a result, TEAMS can leave behind a business model for future cross-organization modeling and simulation funded efforts outside of the torpedo community whose objective is to achieve interoperability within their modeling and simulation domain area.

3. Guidelines and descriptive business best practices offering examples of applying TOGAF methods and procedures to improved product/service quality from concept to implementation.

The only Synergy Project deliverable that has not been achieved to the satisfaction of the Synergy Project Team has been the development of guidelines and descriptive best practices offering examples of applying TOGAF methods and procedures to "improve product/service quality from concept to implementation". We feel we have done this to an anecdotal degree with TEAMS, but this area could certainly be bolstered by broader proof-of-concept participation.

4. Guidelines on how TOGAF practitioners can use the metamodels and profiles based on OMG specifications to represent their work products.

The project delivered a mapping of each TOGAF ADM work product to one or many OMG specifications and then specifically to one or many meta-elements within those specifications. The OMG specifications provide the semantics and syntax of how to represent each ADM work product and how that ADM work product might be related to other modeling elements referenced by the OMG specification.

For example, the mapping (see Appendix A: TOGAF ADM/MDA Mapping) identifies an ADM Business Principle as being represented with a Business Policy in the BMM. In turn, the BMM specifies that:

- A Business Policy governs a Business Process.
- A Business Rule is derived from a Business Policy.
- A Business Policy is a type of Directive which supports the achievement of a Desired Result, is motivated by a Potential Impact, and governs a Course of Action.

This level of detail is not specified in the ADM – it does not specify that Business Rules, Directives, Potential Impacts, or Courses of Action are related or required work products (but also does not necessarily preclude them from being used either).

Also, by providing the practitioner with a set of formal specifications for representing ADM work products, this helps them to select, procure, configure, and use tools that implement those specifications.

In the appendices we provide actual models, developed in MDA specifications, of the work products and processes for all ADM phases.

5. Assessment of applying an MDA modeling approach to TOGAF work products and processes; for example, answering questions such as: are all ADM building blocks modeled the same way?

As mentioned earlier, TEAMS work products from TOGAF are more meaningful and usable (e.g., in different tools and different technologies and platforms) when formally modeled using OMG specifications. Formally modeling requirements allow for traceability from architecture vision, business processes, and data and applications architectures down to the technology architecture. It also ensures that TEAMS technology architecture satisfies business requirements and meets business goals and objectives. As a result of using OMG specifications to formalize TEAMS' business processes, data, and applications architecture work

products, TEAMS can leave behind a business model for future cross-organization modeling and simulation efforts whose objective is to achieve interoperability within their modeling and simulation domain area.

Modeling Activity

There has been considerable parallel effort taking place over the two plus years since the Synergy Project was initiated. As indicated above, there were parallel modeling efforts of TEAMS Proof-of-Concept and the modeling of TOGAF ADM itself. Separate teams were established for each of these efforts: the TEAMS project members for the former and the Synergy Project Modeling Team for the latter. How they accomplished their individual team goals is explained below:

TEAMS

Because TEAMS was already using the TOGAF process to develop a technology architecture, and invoked MDA principles when capturing technology work products in both UML and SysML, they were selected as the first proof-of-concept for validating the synergy between TOGAF and MDA.

They next worked with OMG and Open Group Synergy Project members to complete a one-to-one mapping of TOGAF work products and subcomponents of work products to individual elements of OMG specifications. They leveraged the expertise of the SPEM model developers, as well as the knowledge of OMG experts who developed and selected the modeling specifications to complete a mapping of TEAMS-specific ADM work products to OMG modeling standards. They then reworked the remaining TEAMS TOGAF work products, originally represented in text or graphical form, to also be represented in OMG specifications such as BMM for Phase A and B Business Architecture work products, and SysML Requirements Blocks for requirements of all phases.

Synergy Project Modeling Team

The foundation of the ADM SPEM model was started by identifying all ADM work products that are represented as inputs and outputs for each phase of the ADM Development Cycle (Figure 5) as described in TOGAF 8.1. One thing that had to be done was some reconciliation as to the names of the work products. For example, one of the inputs into Phase B: Business Architecture is “Business Architecture Version 1”, while one of the outputs of Phase B is “Target Business Architecture Version 2”. The modeling team decided in this case that these actually were the same work product (the “Business Architecture”), but the work product changed state (from a high-level initial draft to a more refined complete version). The work products were captured as classes in the SPEM model using its UML profile.

Then the behavioral model was built using UML activity diagrams. Figure 10 shows Phase A: Architecture Vision workflow using a UML activity diagram. The entire phase is represented as a single activity with the input and output work products shown as object flows. The ADM SPEM model has more detailed activity diagrams for each phase showing the corresponding steps (if the phase has steps specified in TOGAF). One thing the modeling team wanted to do was represent the inputs and outputs of each sub-activity or step within a phase. For example, in Figure 9 (the steps of the Architecture Vision phase), it seemed useful to represent what individual work products were the input to the “Establish Project” activity and the resulting outputs. However, since TOGAF 8.1 does not get to this level of specificity, the modeling team determined that, while potentially helpful, it departed from what TOGAF 8.1 actually specified – this would be considered an inference or interpretation (which would result in a different variant of the ADM from TOGAF 8.1).

After the activity diagrams were created, each work product was mapped to one or many OMG specifications. Then each work product was mapped to one or many specific metaclasses in the respective

specification(s). Appendix A: TOGAF ADM/MDA Mapping shows many of the work products that appear in Phase A: Architecture Vision and Phase B: Business Architecture. The implied traceability relationships between each work product were determined by analyzing the inputs and outputs of each phase and the mapping of each work product to the selected OMG specification. Appendix A shows some of ADM work products involved in Phase A and their traceability relationships using a UML class diagram.

In the cases where multiple OMG specifications might have been appropriate, specific selections were made that were determined to be the best for the TEAMS project, but do not represent the only choice for all types of organizations. Also, some work products, especially those that are composite work products, did not have obvious direct mappings. For example, in the case of the Business Architecture work product, two of its constituent elements (Business Process and Organization Unit) were mapped to specific classes in the Business Motivation Model specification (BMM).

Once the complete SPEM process model for TOGAF 8.1 was created, the team informed The Open Group Architecture Forum regarding some of the inconsistencies identified through the modeling effort. This was a major contributor to the creation of TOGAF 8.1.1. Then, an independent review (not a part of the modeling team), reviewed the model and compared it to the updated TOGAF 8.1.1 standard. Over 100 defects were identified in the model (most of the defects were not significant). The independent reviewer then made the changes to the model to reflect the required updates.

A note on modeling tools

While at the time of writing this White Paper there is a new version of SPEM (veVrsion 2.0), when the modeling effort began in 2005, SPEM 1.1 was the only officially adopted version of this specification. SPEM 1.1 is described as a MOF 1.3 metamodel and also has a UML profile for UML 1.4. As the modeling team wanted to leverage UML modeling capabilities, this meant that the team had to use a UML 1.4 modeling tool that fully supported UML 1.4 profiles. This led the team to select one of the few tools that was still available that was UML 1.4-compliant – MagicDraw 9.5 from No Magic (which provided free licenses of its Enterprise MagicDraw UML tool to the project). With this phase of the Synergy Project having been completed, there is interest in migrating the TOGAF ADM SPEM 1.1 model to SPEM 2.0 to leverage the capabilities of UML 2.0 modeling tools and the significant new capabilities in SPEM 2.0.

The ADM SPEM model was built by three team members located across the globe using MagicDraw. By using MagicDraw's standard reporting capabilities, the team has published the activity diagrams and class diagrams that comprise the visual aspect of the process model. MagicDraw was also used to create an XMI 1.1 export of the SPEM 1.1 model.

Collaboration

Project Team Meetings: In order to keep these two major efforts in synchronization, the Synergy Project Team undertook a number of what proved to be very effective internal communications efforts.

- **Teleconferences**: The Synergy Project held bi-weekly hour-long teleconferences which always had a very specific agenda. Minutes of these bi-weekly teleconferences were recorded and distributed to all the participants on the specialized and focused mailing list (mda-togaf@opengroup.org).
- **Face-to-face**: These meetings were held on at least a quarterly basis and proved to be some of the most productive (and fun) times over the course of the Synergy Project. We would meet either at an OMG Technical Conference or an Open Group quarterly conference. We also held face-to-face meetings at the IC annual summit. These meetings were usually scheduled for a full day and were spent aligning both modeling efforts with each other and/or developing the appropriate mappings necessary for the Proof-of-

Concept to proceed. All three participating organizations supplied working space for these face-to-face meetings.

- **Individual work**: As is always the case, it is the individual participants in the effort who do the bulk of the work. Individual Synergy Project Team members spent untold hours of their own time and effort in helping the team reach its end results.
- **Logistics**: As indicated above, all three sponsoring organizations – OMG, The Open Group, and the IC – provided logistical support when and where needed. Of particular importance to the internal communications of the project was the online email and web support supplied by The Open Group "Plato" facility.

In addition to the two modeling efforts, there was a Communications Activity responsible for papers such as this, press releases, and managing release of project reports but this report will not discuss that activity. It is ongoing and is supported by the staff of the participating organizations.

Project Influence on Other Industry Activity

The Synergy Project has already attracted interest from other, related industry activities. For example, an effort organizationally unrelated to the project is using Synergy Project models of TOGAF ADM work products as guidance in modeling DoD Architecture Framework (DoDAF) work products. Within The Open Group, its Architecture Forum has been motivated by this project to undertake an assessment of modeling TOGAF ADM in the Eclipse Process Framework (EPF). EPF's modeling core is based upon OMG's Meta Object Facility (MOF) specification and is planned to align with OMG's Software Process Engineering Metamodel 2 (SPEM) specification once completed.

Future Plans

Having devoted two plus years to the current "phase" of the Synergy Project, most of the team participants would like the work to continue and be refined. This section identifies potential follow-on or "next phase" work that would benefit the participating organizations and the enterprise architecture profession. The main efforts could include:

- Further validating and refining the integration of the TOGAF framework with the MDA specifications, expanding the scope to include additional, primarily commercial proofs-of-concept. This may also provide for more rigorous feedback, especially to the OMG on the MDA specifications.
- Refining and updating the TOGAF ADM SPEM process model to the latest version of SPEM. This will allow further refinement of TOGAF and the capability to further define the process. (Note that this work may be undertaken by The Open Group Architecture Forum as part of its TOGAF development work.)
- Developing a formal modeled mapping of TOGAF ADM work products to the MDA specifications. This will allow practitioners the ability to better track versioning of both TOGAF an MDA over time.

Appendix A: TOGAF ADM/MDA Mapping

This appendix provides a mapping of TOGAF ADM work products and processes to MDA specifications.

The following table identifies MDA specifications referenced in this appendix. See References for how to access the specifications.

Acronym	Specification Name	Reference
BMM	Business Motivation Model	Not yet formally published.
BPDM	Business Process Definition Metamodel	Not yet adopted.
BPMN	Business Process Modeling Notation	Not yet formally published.
CWM	Common Warehouse Metamodel	See References.
EAI	UML Profile for Enterprise Application Integration	See References.
EDOC	UML Profile for Enterprise Distributed Object Computing	See References.
FTFM	Federal Transition Framework Metamodel	Not yet adopted.
IMM	Information Management Metamodel	Not yet adopted.
ITPMF	IT Portfolio Management Facility	Not yet formally published.
KDM	Knowledge Discovery Metamodel	Not yet formally published.
MOF	Meta Object Facility	See References.
ODM	Ontology Definition Metamodel	Not yet formally published.
OSM	Organization Structure Metamodel	Not yet adopted.
QVT	MOF Query/Views/Transformations	Not yet formally published.
RAS	Re-usable Asset Specification	See References.
SBVR	Semantics of Business Vocabulary and Business Rules	Not yet formally published.
SPEM	Software Process Engineering Metamodel	See References.
SySML	OMG Systems Modeling Language	Not yet formally published.
UML	Unified Modeling Language	See References.
UPDM	UML Profile for DoDAF and MODAF	Not yet formally published.
UPMS	UML Profile and Metamodel for Services	Not yet adopted.
XMI	XML Metadata Interchange	See References.

The following table maps ADM work products to OMG specifications. (In some cases, there may be a one-to-many relationship.) No entry in the "Primary Specification Element" column should be interpreted as there being many elements within the specification which semantically capture the work product and not a single primary element.

ADM Work Product	OMG Specification(s)*	Primary Specification Element(s)	Comments
Applications Architecture			
— Place Systems Model	SysML	SysML::internal block	
— Process Systems Model	UML, SysML, BPMN, BPDM	UML, SysML::Activity	
— Time Systems Model	UML, SysML	UML,SysML::Activity	
— Application Interoperability Requirements	SysML, EAI, UPMS*	SysML::Requirement	
Applications Architecture Report	BMM, OSM*		
Applications Baseline Description	Part of Applications Architecture		
Applications Principles	BMM, SysML	BMM::Business Policy	OCL may be used here and many other places.
Applications Views			
— Application Services View	UML, SysML, UPMS*	UML::Component SysML::internal block	
— Application Interoperability View	UML, SysML, EDOC, EAI	UML::Component SysML::internal block	
— Application Information View	ITPMF, UPMS*, EDOC		Relate data to applications – same piece of data may support multiple applications.
Architecture-compliant Implemented System	ITPMF, RAS		
Architecture Contract	BMM	BMM::Directive	
Architecture Principles	BMM	BMM::Business Policy	
Architecture Updates	Anything that could be a part of any architecture		
Architecture Vision	See Business Scenario	BMM::Vision	
Architecture Vision/ Business Scenario	See Business Scenario		
Business Architecture	UML, BPMN, BPDM, OSM*, SBVR, BMM, ITPMF	BMM::Business Process	Business Architecture is a composite work product that contains many elements that need to be identified and individually mapped to different metaclasses.
— Organization Structure	BMM, OSM*	BMM::Organization Unit UML::Package	
— Business Functions	UML	UML::Activity	
— Business Services	UML, BMM, BPDM	UML::Use Case BMM::Business Process	
— Business Processes	UML, BMM, BPDM	UML::Collaboration	
— Business Roles	UML, BPDM	UML::Actor UML::Class	

* Specification not yet adopted.

ADM Work Product	OMG Specification(s)*	Primary Specification Element(s)	Comments
— Correlation of Organization and Functions	UML	UML::Association	
Business Architecture Report	BMM, OSM		
Business Architecture Version 2	Same as Business Architecture		
Business Baseline Version 2	Same as Business Architecture		Remove "Version 2".
Business Drivers	BMM	BMM::Assessment	
Business Goals	BMM	BMM::Goal	
Business Principles	BMM	BMM::Business Policy	
Business Requirements	SysML, BMM	BMM::Directive SysML::Requirement	
Business Scenario	UML, BPMN, BPDM, OSM, SBVR, BMM, ITPMF	Business use-case, external business process	Might be same as Architecture Vision, could be a technique/process, might be a part of Arch Vision.
Business Strategy	BMM	BMM::Strategy	
Data Architecture	CWM, ODM, BPDM, ITPMF, EDOC	CWM::Package	
— Business Data Mgmt Process Model			
— Business Data Model	UML, SysML	UML::Class SysML Block	
— Logical Data Model	UML, SysML	SysML::Block	
— Data Entity/Business Function Matrix			
— Data Interoperability Requirements	SysML	SysML::Requirement	
Data Architecture Report	BMM, OSM		
Data Baseline Description	Part of Data Architecture		
Data Principles	BMM	BMM:Business Policy	
Data Views			
— Data Dissemination	SysML	SysML::FlowPort	Operations on a class – actual or implied traceability.
— Data Lifecycle	SysML	SysML::Activity	
— Data Security			
— Data Model Management	CWM, IMM*, QVT		
Enterprise Continuum	RAS and everything else	RAS::Asset	Asset can be comprised of any number of artifacts (and subsequently point to any other OMG spec.); does not have to be a "software" asset.

ADM Work Product	OMG Specification(s)*	Primary Specification Element(s)	Comments
Framework Definition	SPEM and BMM	SPEM::Process BMM::Business Process	Organization-specific tailored process framework; identified as one or many BMM::Business Processes and described using SPEM 2 (process content [such as TOGAF], integrated with other process content [such as ITIL, CoBIT, etc.] and tailored using SPEM 2).
Gap Analysis	BMM	BMM::Weakness	Process used to produce Gap Analysis Results.
Gap Analysis Results	KDM, QVT, MOF Versioning		Traceability matrix? How to represent a specific gap?
High-level Implementation Plan	SPEM2, ITPMF, BMM, OSM	BMM::Tactic	We need to add a new work product for Detailed Implementation and Migration Plan. How to represent a migration task (and its relationship to a solution gap/impact)?
Impact Analysis	MOF, QVT, BMM, ITPMF	BMM::Potential Impact	How to represent an actual impact?
Implementation and Migration Strategy	BMM		
IT Governance Strategy	BMM	BMM::Tactic	
Other Architecture Frameworks	UPDM, FTFM*		
Other Principles	BMM	BMM::Business Policy	
Product Information	RAS, SysML, UML, CWM, KDM, EAI		Whatever supplier can provide (or model on behalf of supplier).
Request for Architecture Change — Business Changes	BMM, ITPMF	BMM::Directive	
Request for Architecture Change — Technology Changes	BMM, ITPMF	BMM::Directive	
Request for Architecture Work	BMM	BMM::Directive ITPMF::Interest	Document, prose.
Solutions Continuum	RAS	BMM::Directive	
Statement of Architecture Work	BMM, SPEM2, ITPMF	BMM::Directive ITPMF::Agreement	Document.
Strategic Drivers	Same as Business Driver		How is this different from Business Drivers?
Target Applications Architecture	Same as Applications Architecture		
Target Business Architecture Version 2	Same as Business Architecture		
Target Data Architecture	Same as Data Architecture		
Target Technology Architecture Version 1	Same as Technical Architecture		
Technical Principles	BMM, SysML	BMM::Business Policy	

ADM Work Product	OMG Specification(s)*	Primary Specification Element(s)	Comments
Technical Requirements	SysML, UML	SysML::Requirement	
Technology Architecture	UML, ITPMF, EDOC, SysML, RAS		
Technology Architecture — Gap Report	See Gap Analysis Results		
Technology Architecture Report	BMM, OSM*		
Technology Baseline Description	Part of Technology Architecture		
Technology Principles	BMM	BMM::Business Policy	
TOGAF ADM	SPEM, BPMN, BPDM		
Viewpoints	QVT		IEEE 1471
Views	UML, BPMN, BPDM, OSM, SBVR, BMM, ITPMF, MOF		Derived from models (Business Architecture Description and others) and expressed in appropriate semantics.

Appendix B: Synergy Project Models

This appendix identifies the Synergy Project models for all phases of TOGAF ADM.

Note that phases are modeled using the UML Profile defined in SPEM.

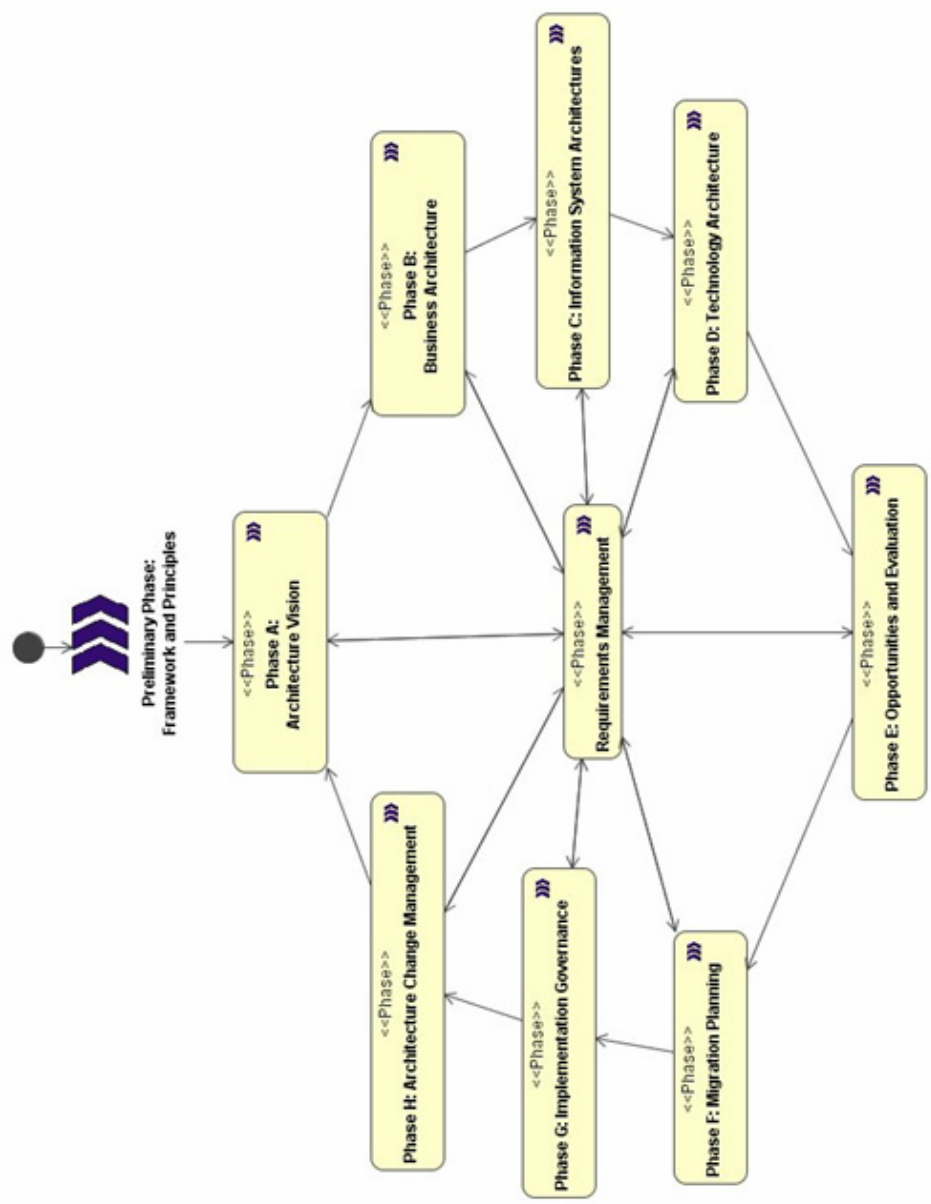

Figure 5: TOGAF ADM Lifecycle

Preliminary Phase: Framework and Principles

There are no steps for "Preliminary Phase: Framework and Principles". The TOGAF ADM is a generic method, intended to be used by a wide variety of different enterprises, and in conjunction with a wide variety of other architecture frameworks, if required. It is not practical to define specific steps for adapting the ADM to such a wide variety of potential contexts. The issues involved are discussed in detail in Adapting the ADM .

Figure 6: Framework and Principles Workflow

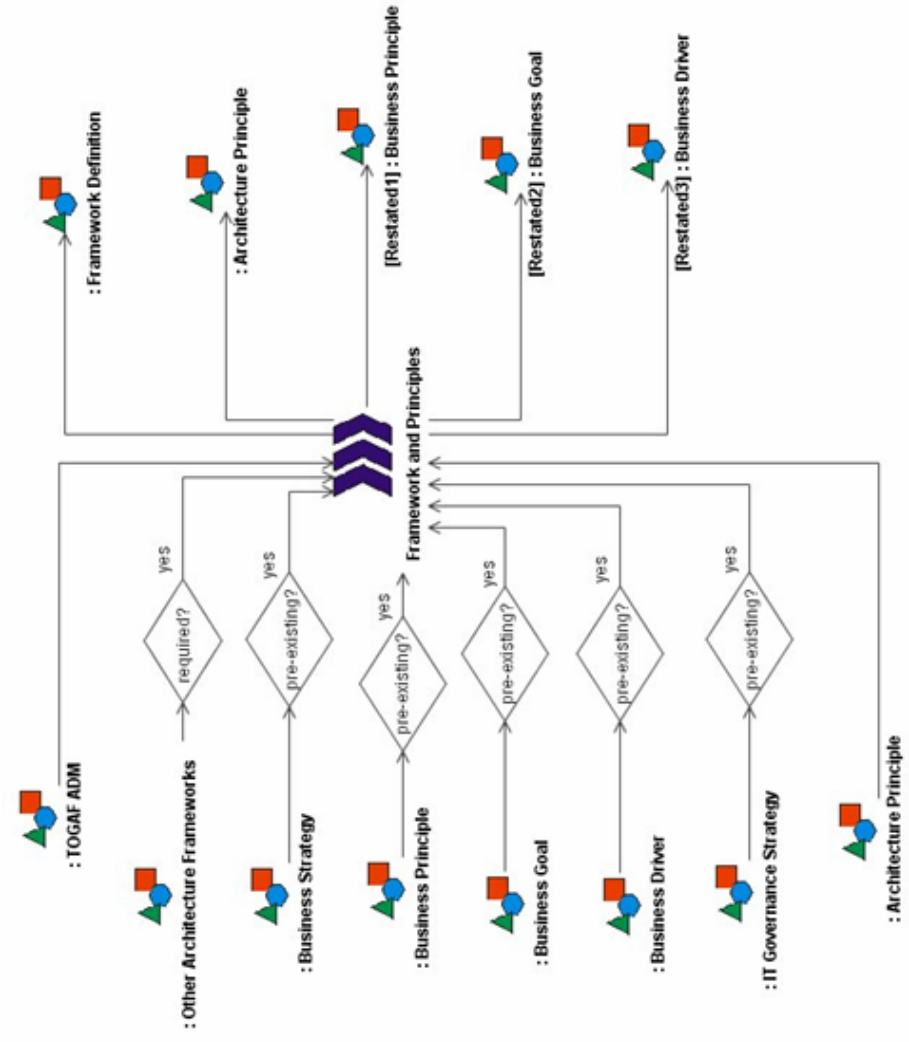

Figure 7: Work Product Inputs and Outputs to Framework and Principles

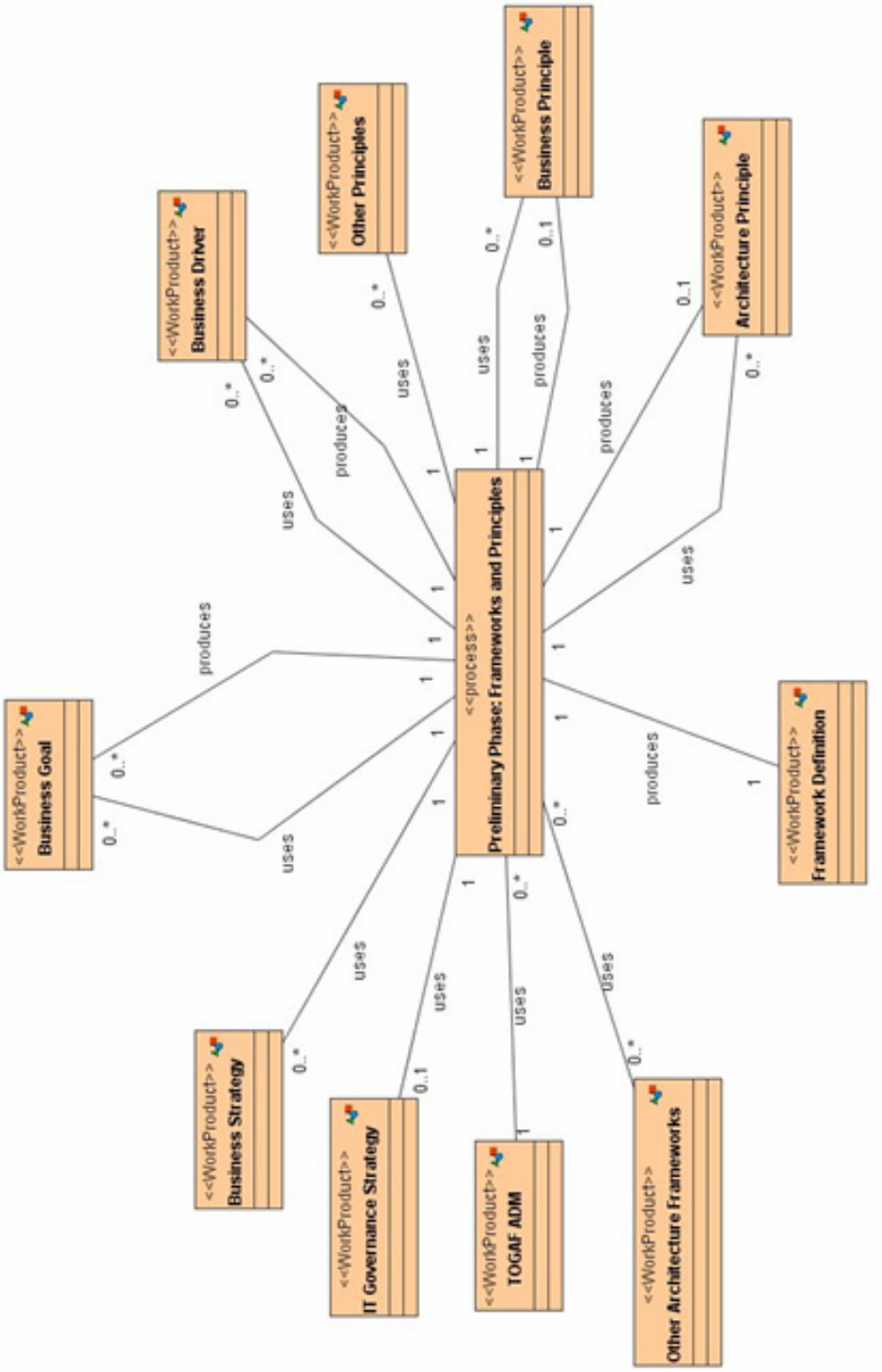

Figure 8: Framework and Principles Work Product Relationships

Phase A: Architecture Vision

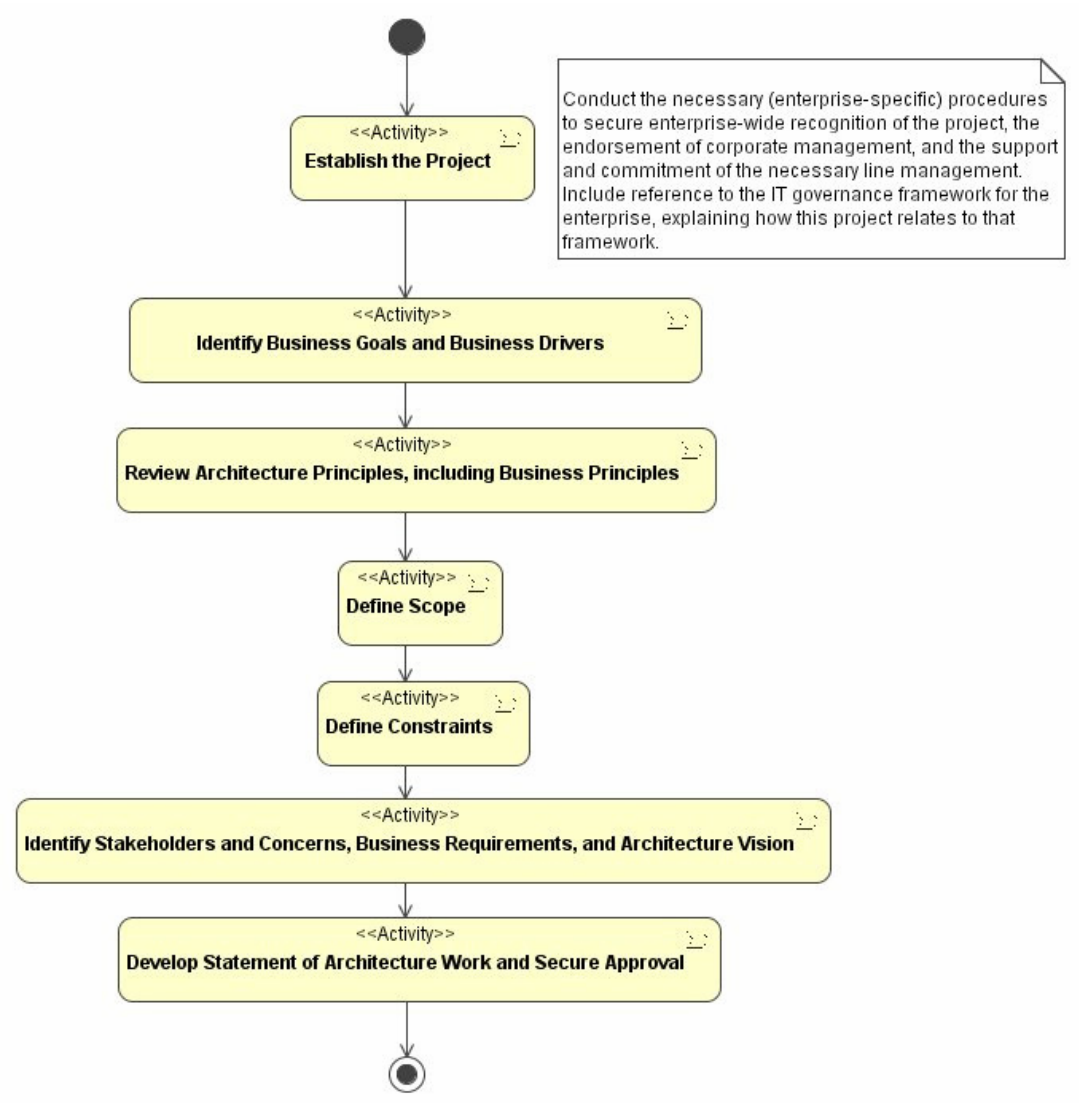

Figure 9: Architecture Vision Workflow

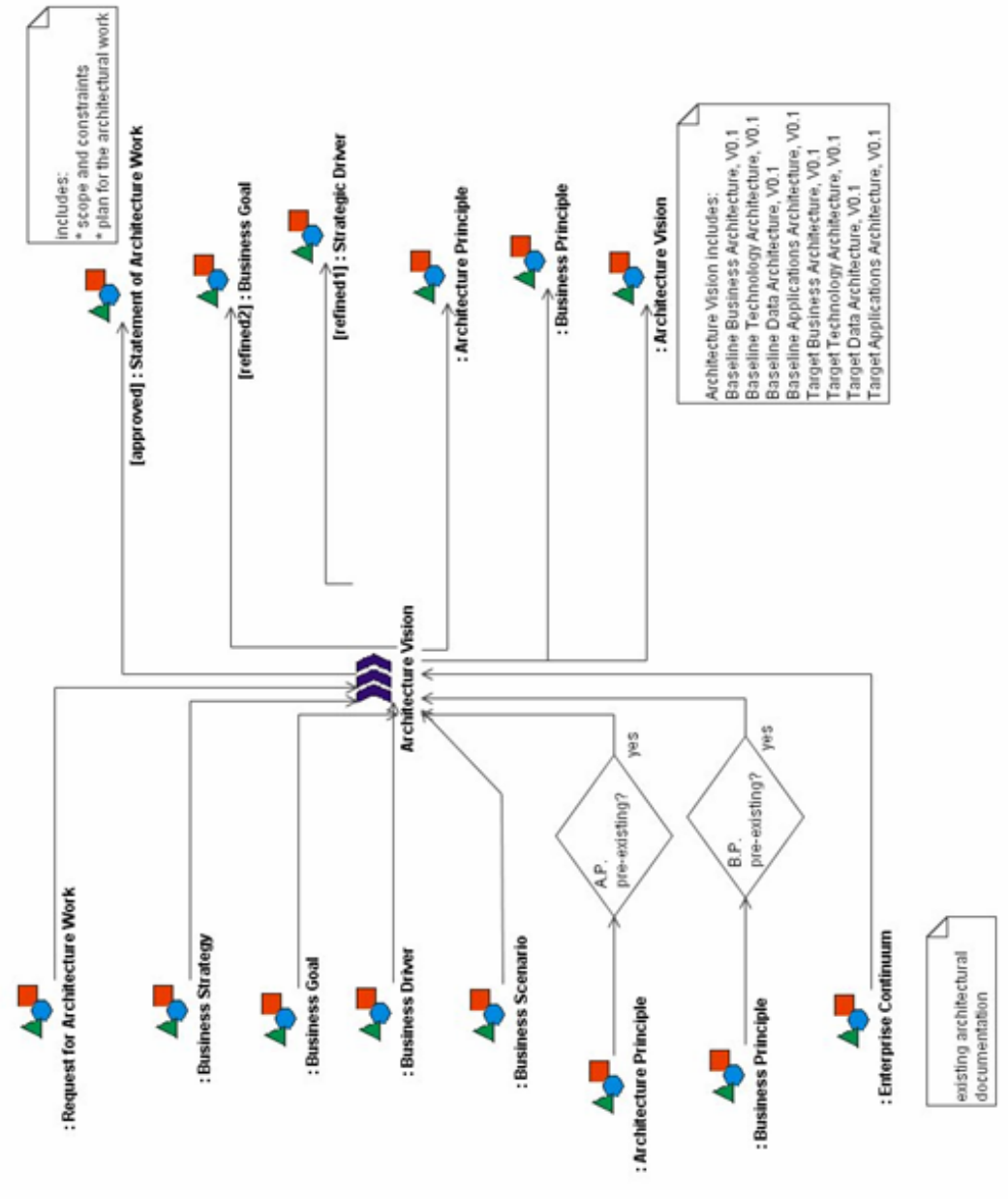

Figure 10: Work Product Inputs and Outputs to Architecture Vision

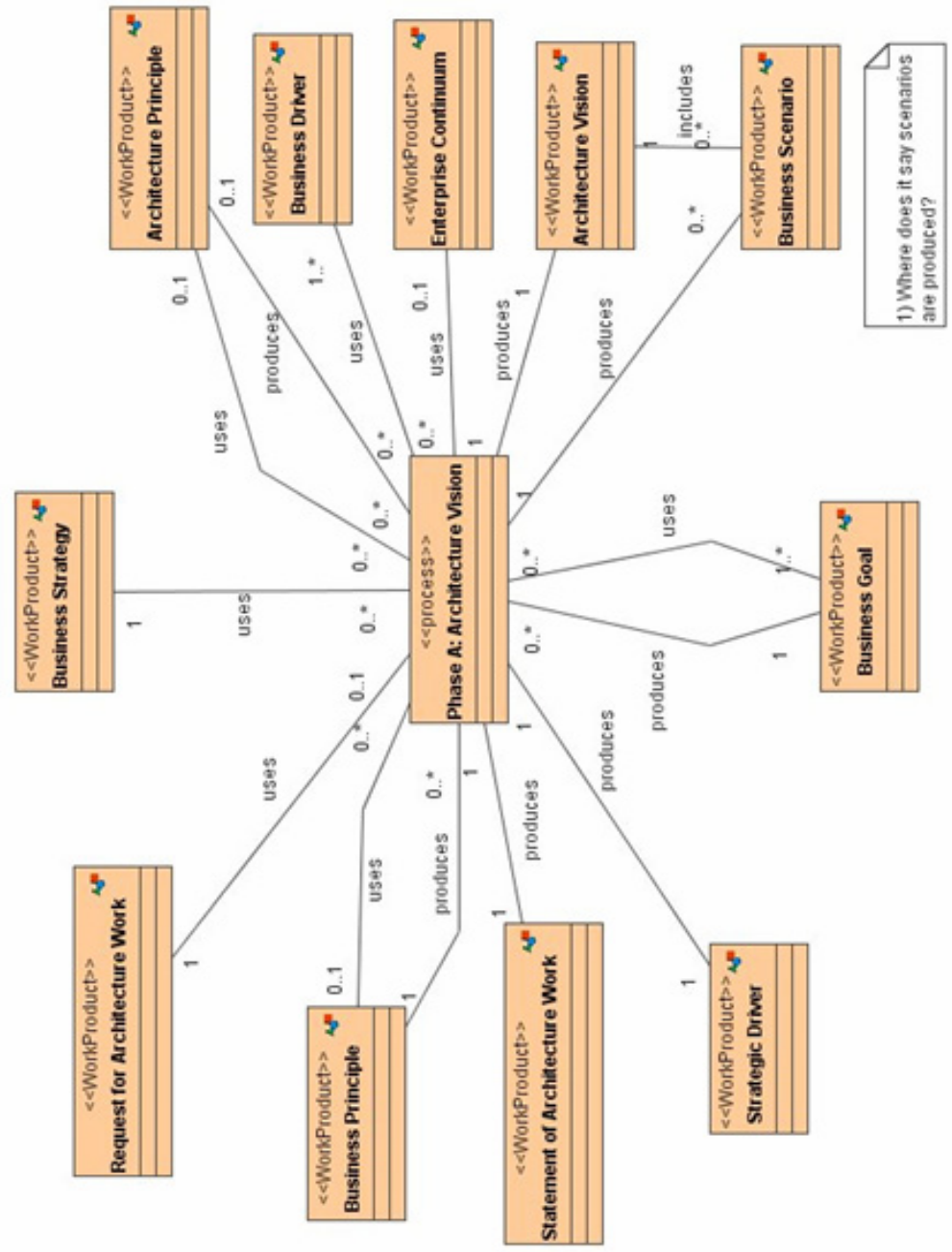

Figure 11: Architecture Vision Work Product Relationships

Phase B: Business Architecture

Note that steps were modeled, but the overall workflow diagram is missing.

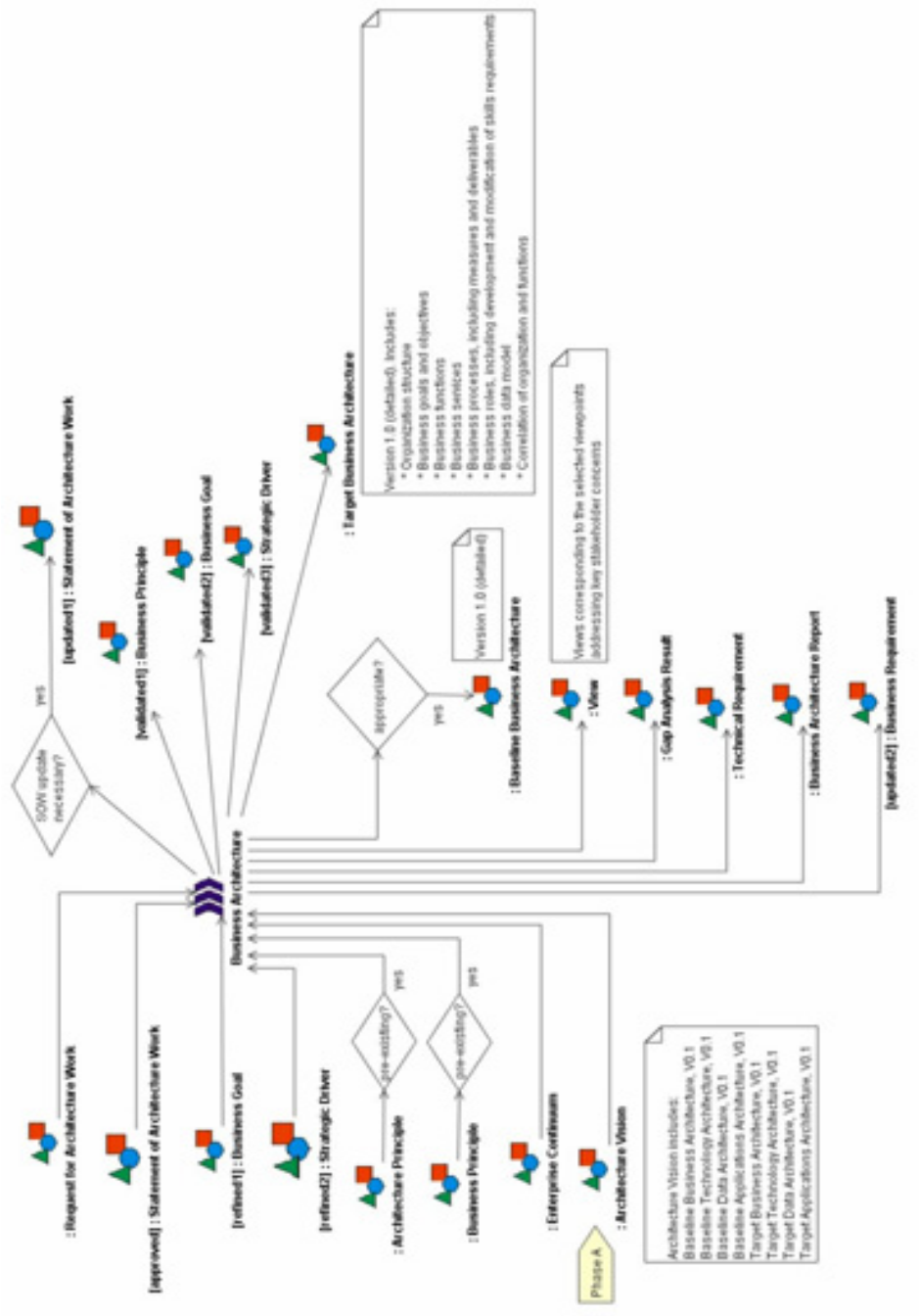

Figure 12: Work Product Inputs and Outputs to Business Architecture

Figure 13: Business Architecture Work Product Relationships

Phase C: Information Systems Architecture

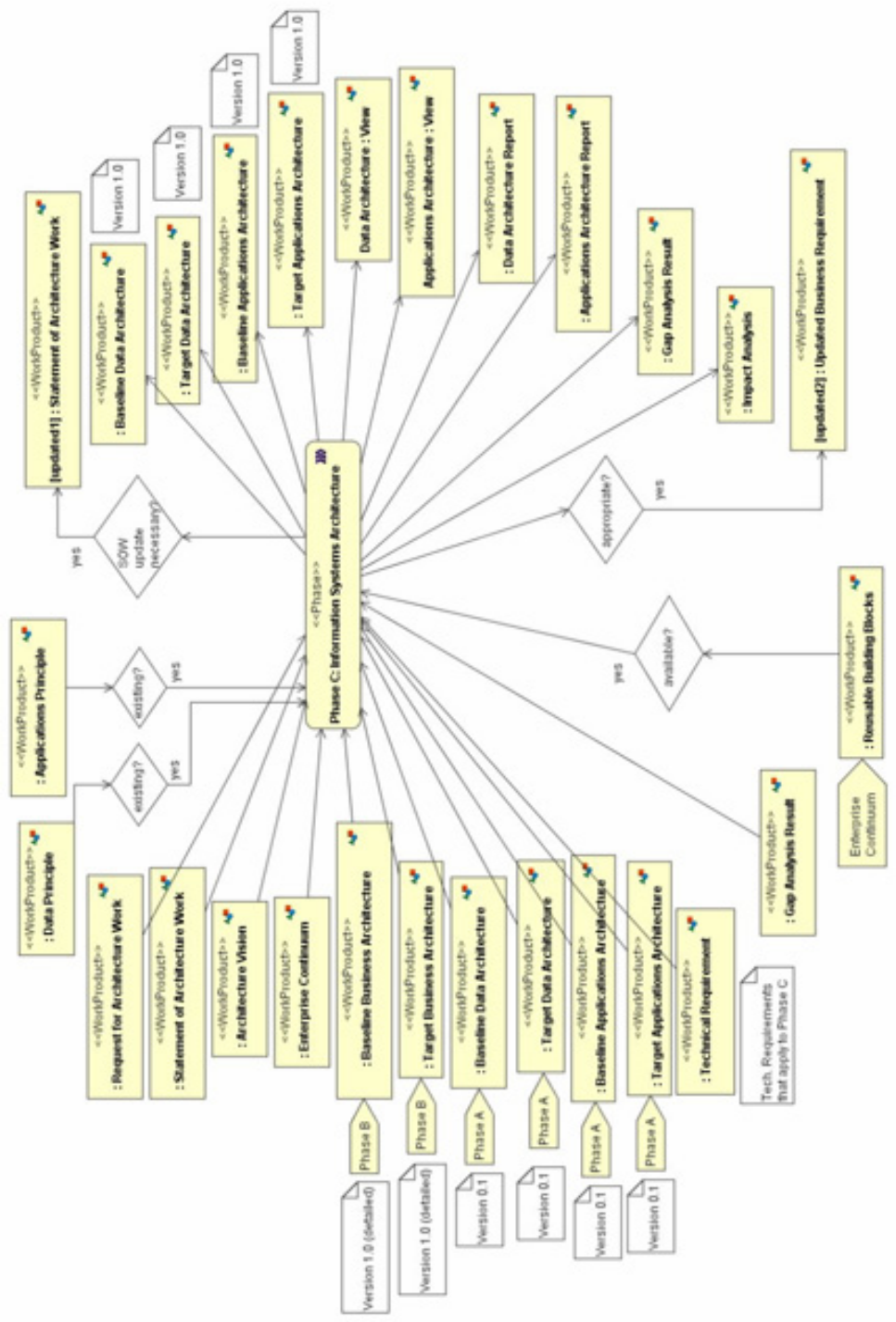

Figure 14: Work Product Inputs and Outputs to Information Systems

Phase C: ISA Applications Architecture

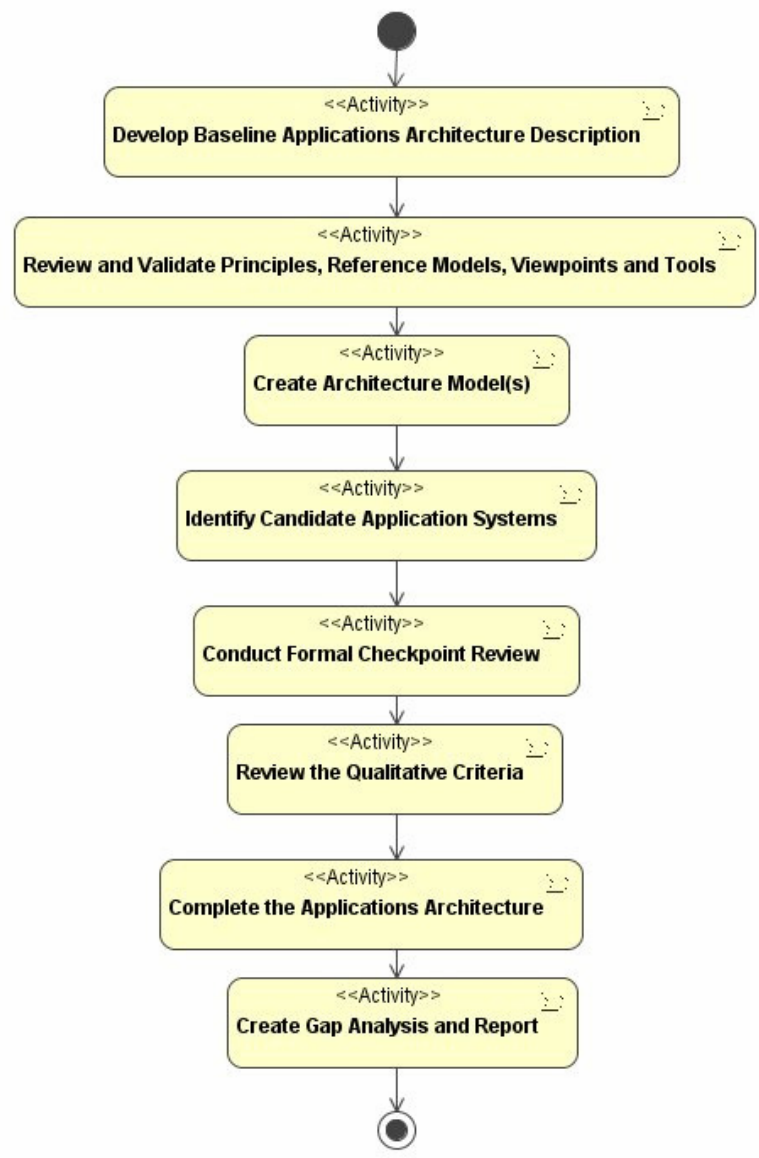

Figure 15: ISA Applications Architecture Workflow

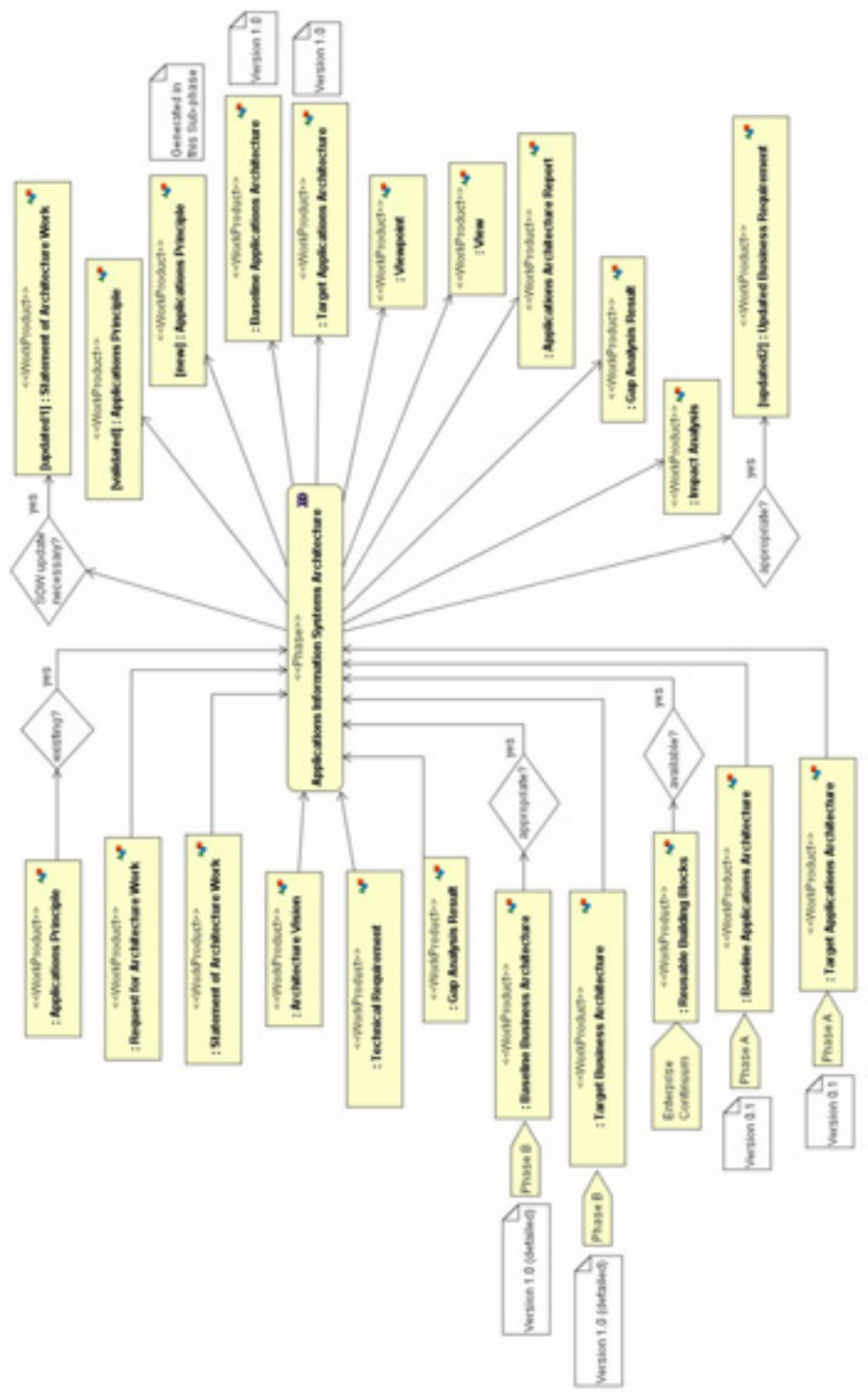

Figure 16: Work Product Inputs and Outputs to ISA Applications Architecture

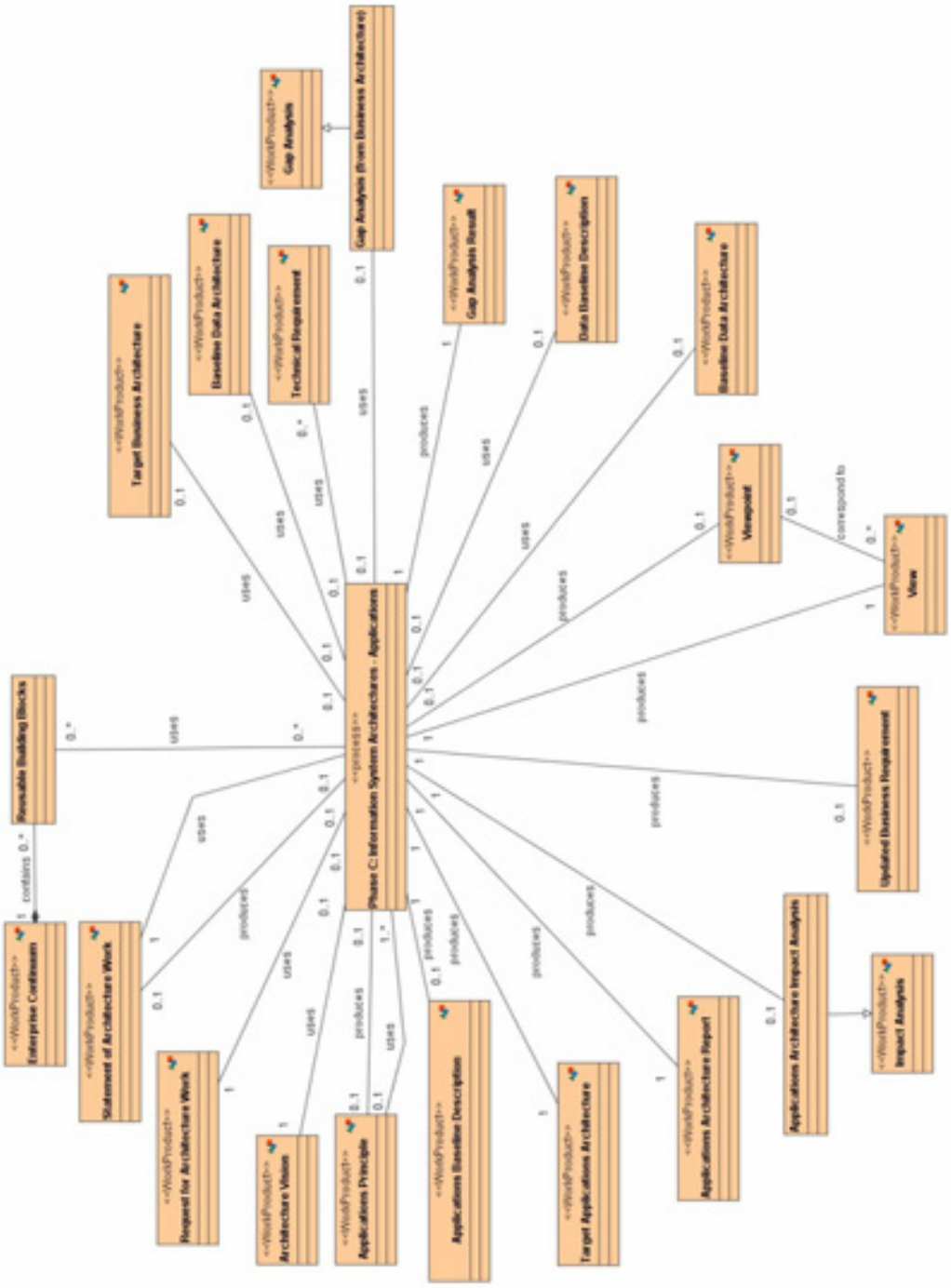

Figure 17: ISA Applications Architecture Work Product Relationships

Phase C: ISA Data Architecture

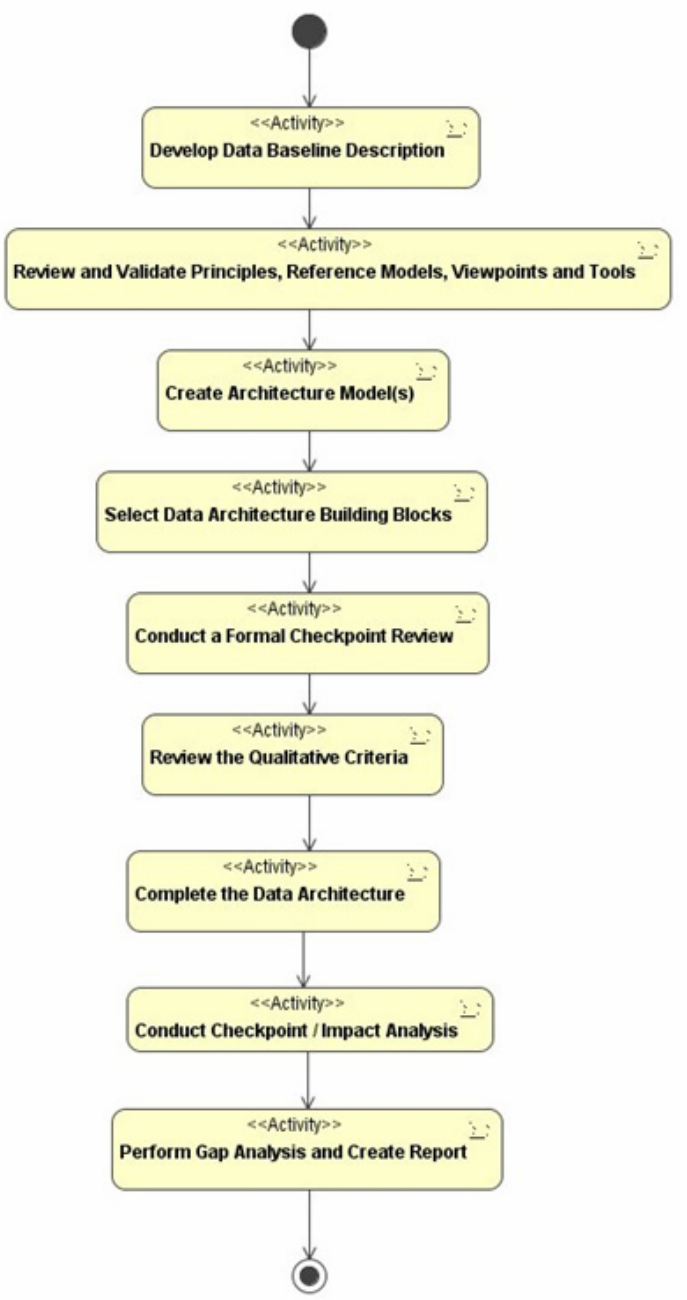

Figure 18: ISA Data Architecture Workflow

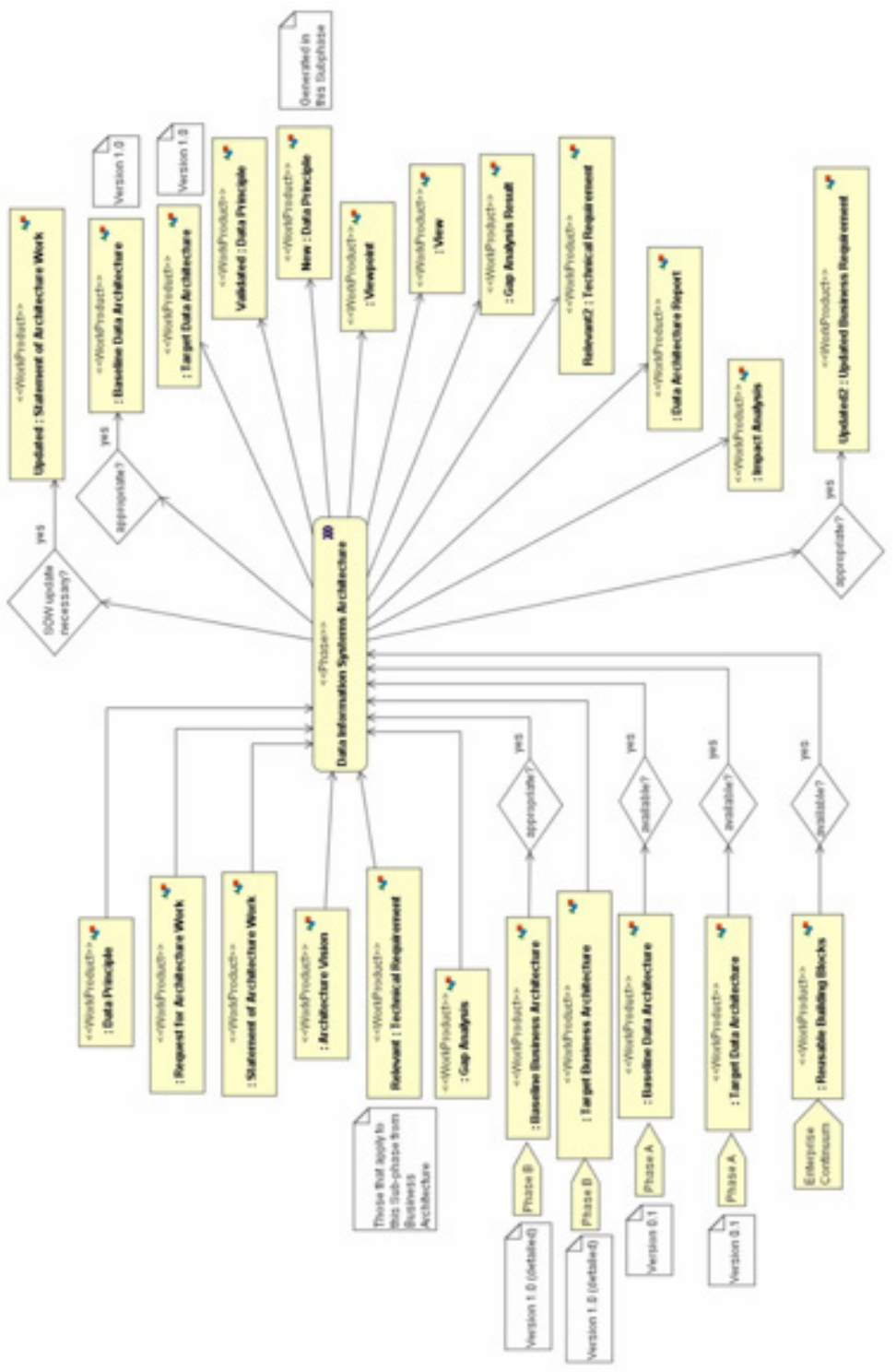

Figure 19: Work Product Inputs and Outputs to ISA Data Architecture

Figure 20: ISA Data Architecture Work Product Relationships

Phase D: Technology Architecture

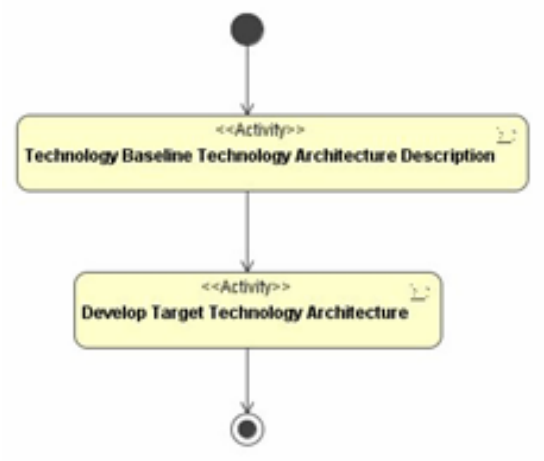

Figure 21: Technology Architecture Workflow

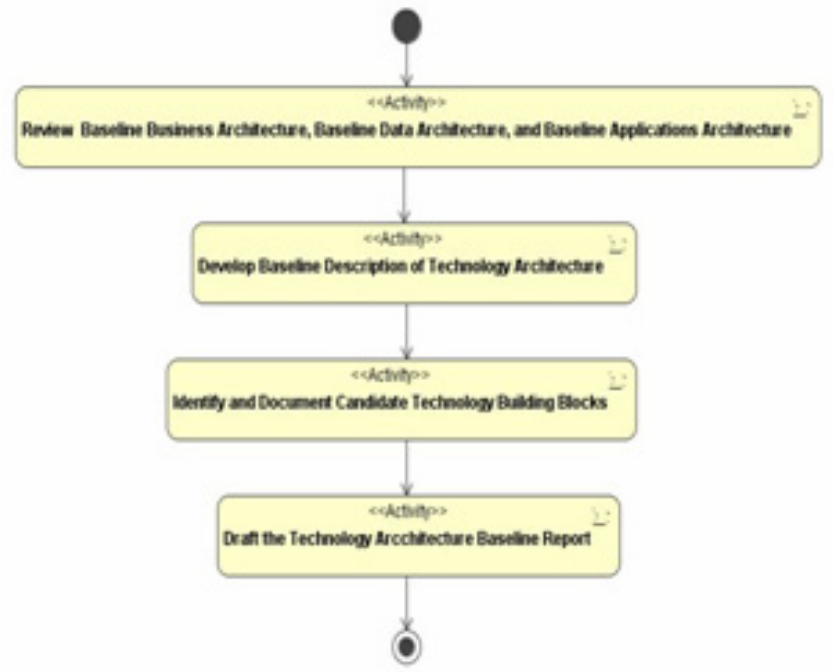

Figure 22: Baseline Technology Architecture Description Workflow

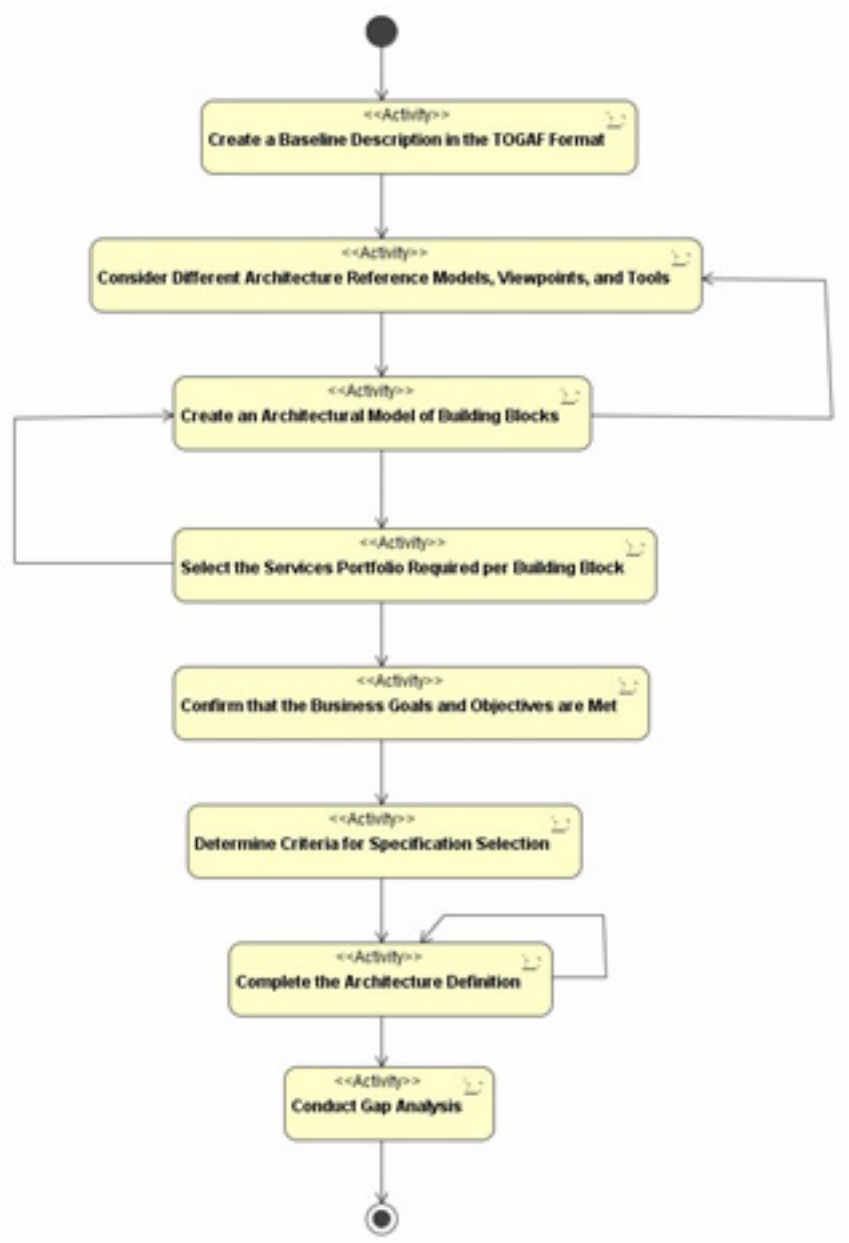

Figure 23: Target Technology Architecture Workflow

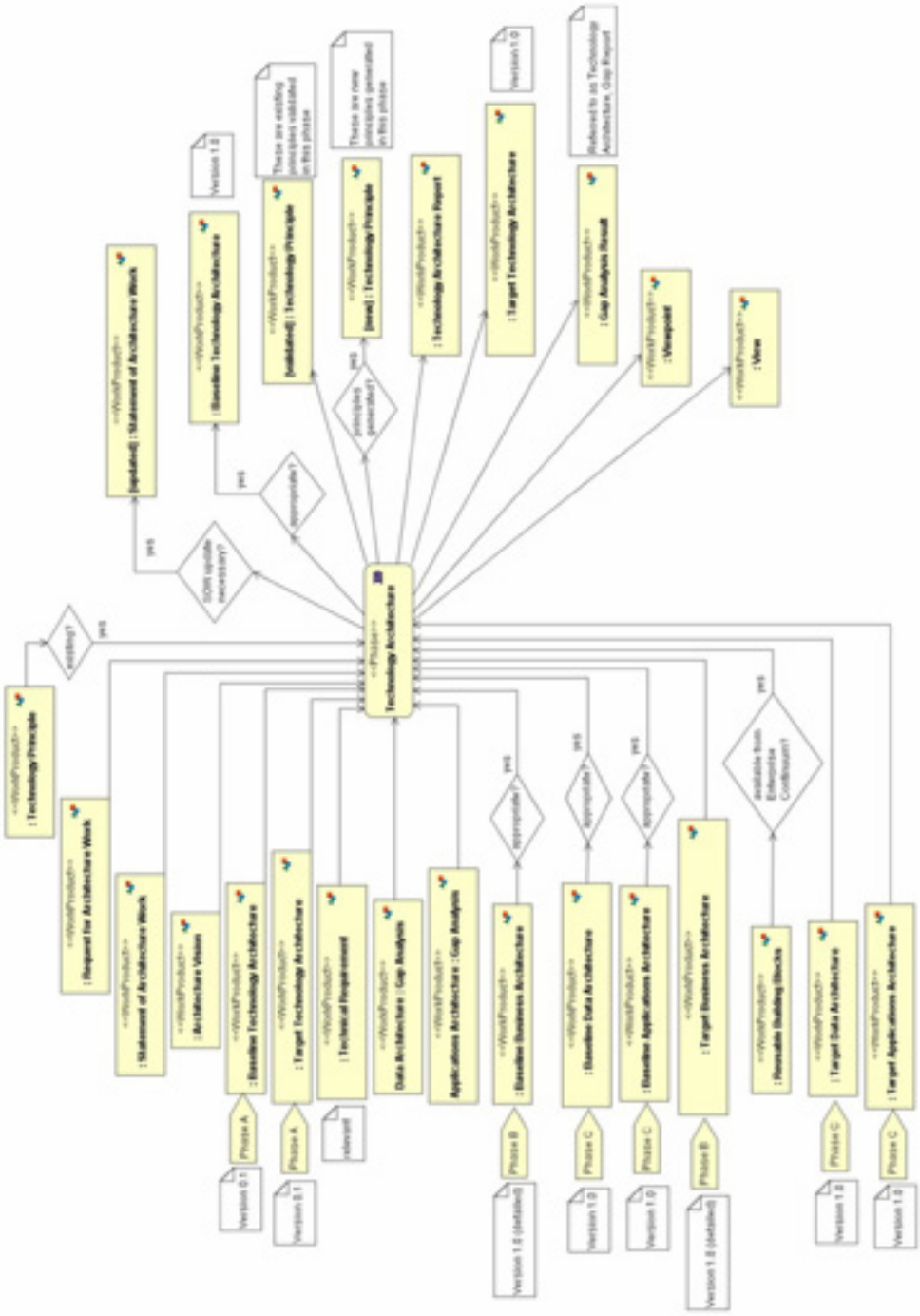

Figure 24: Work Product Inputs and Outputs to Technology Architecture

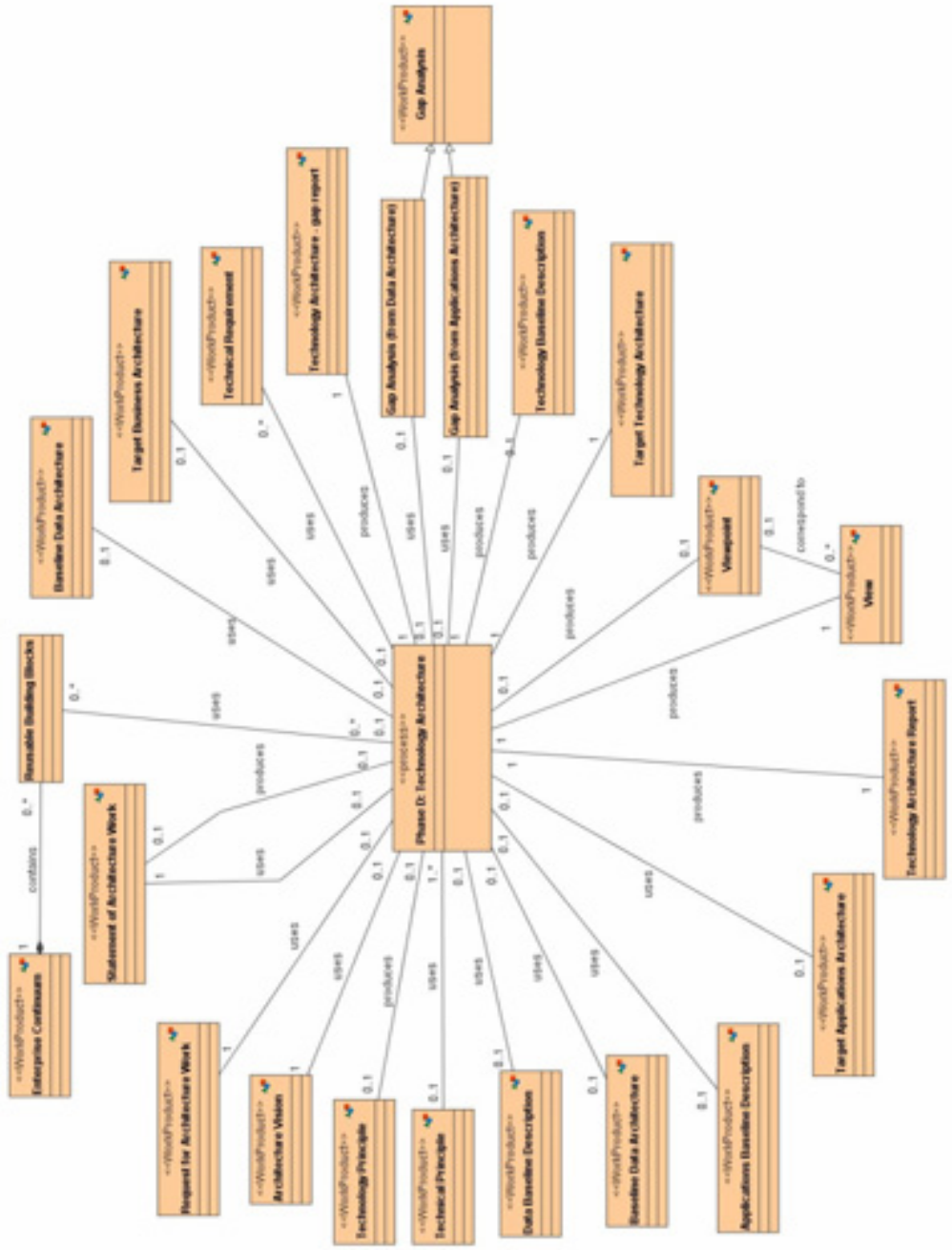

Figure 25: Technology Architecture Work Product Relationships

Phase E: Opportunities and Solutions

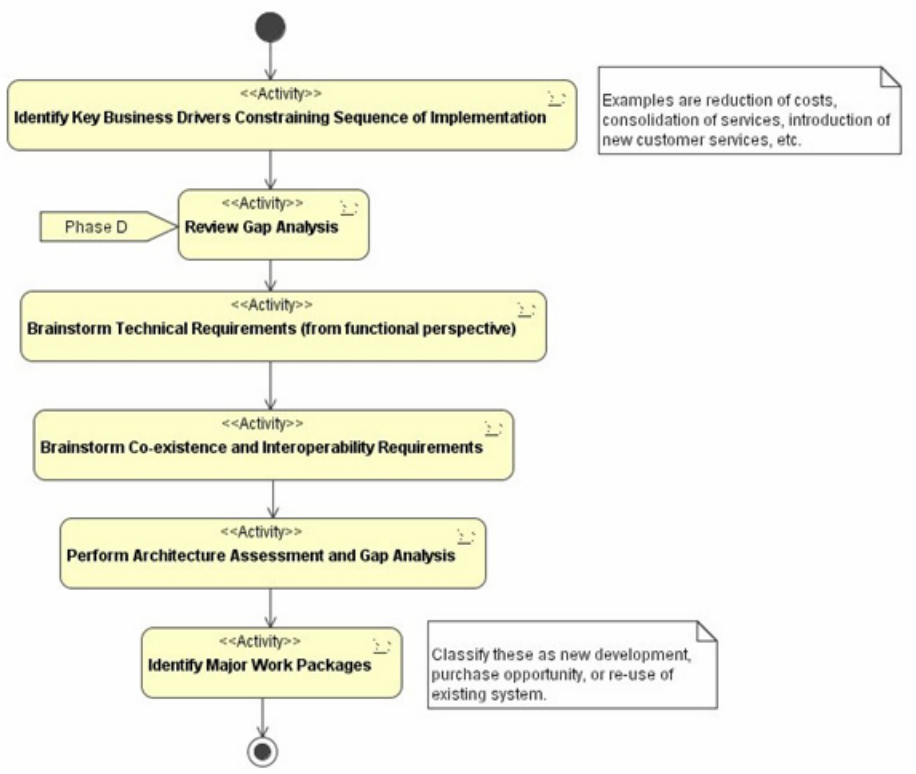

Figure 26: Opportunities and Solutions Workflow

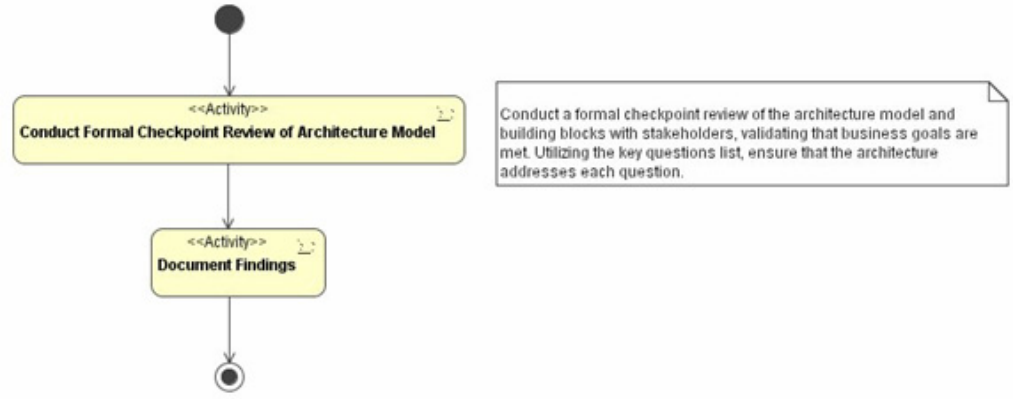

Figure 27: Step 5 – Perform Architecture Assessment and Gap Analysis Workflow

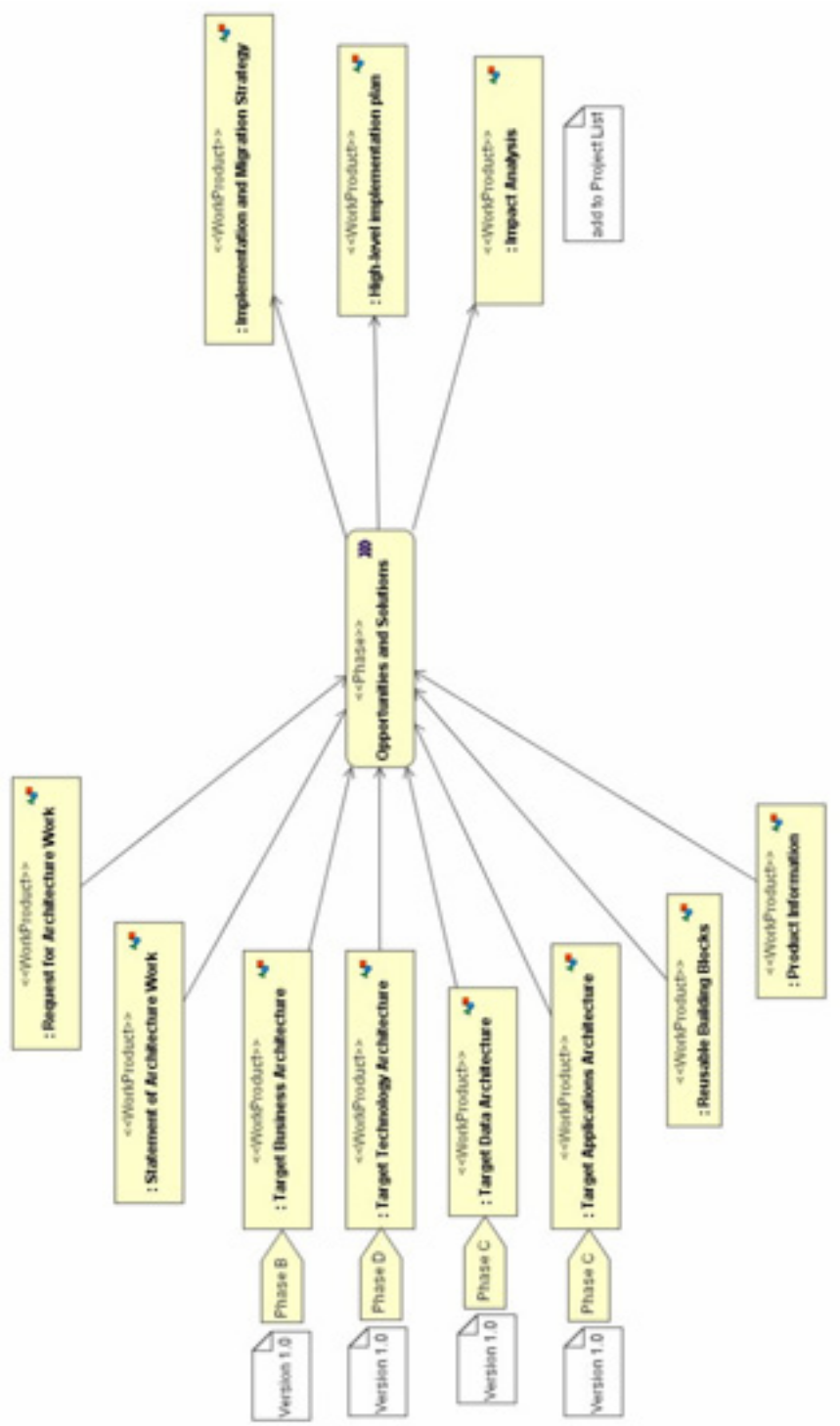

Figure 28: Work Product Inputs and Outputs to Opportunities and Solutions

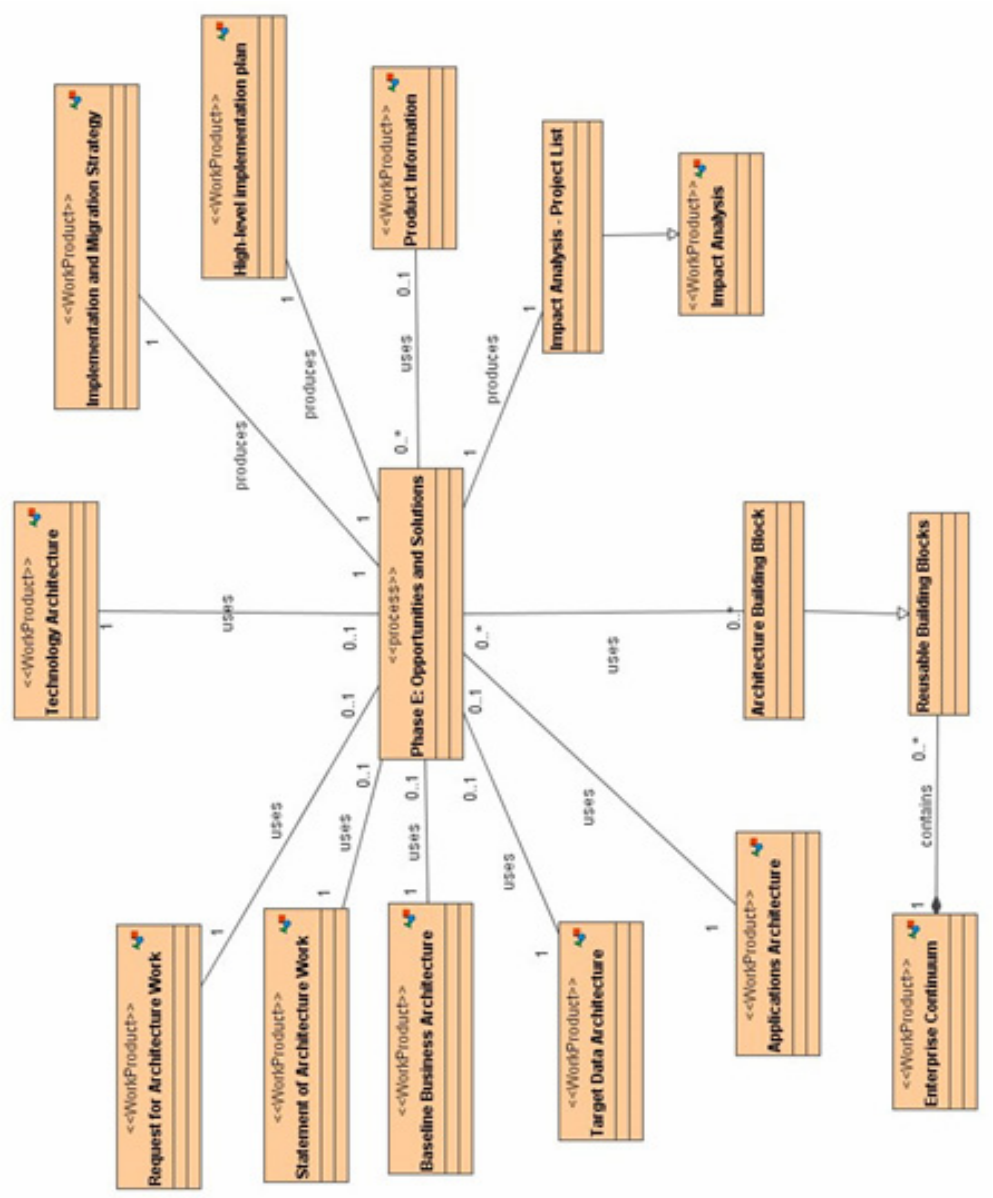

Figure 29: Opportunities and Solutions Work Product Relationships

Phase F: Migration Planning

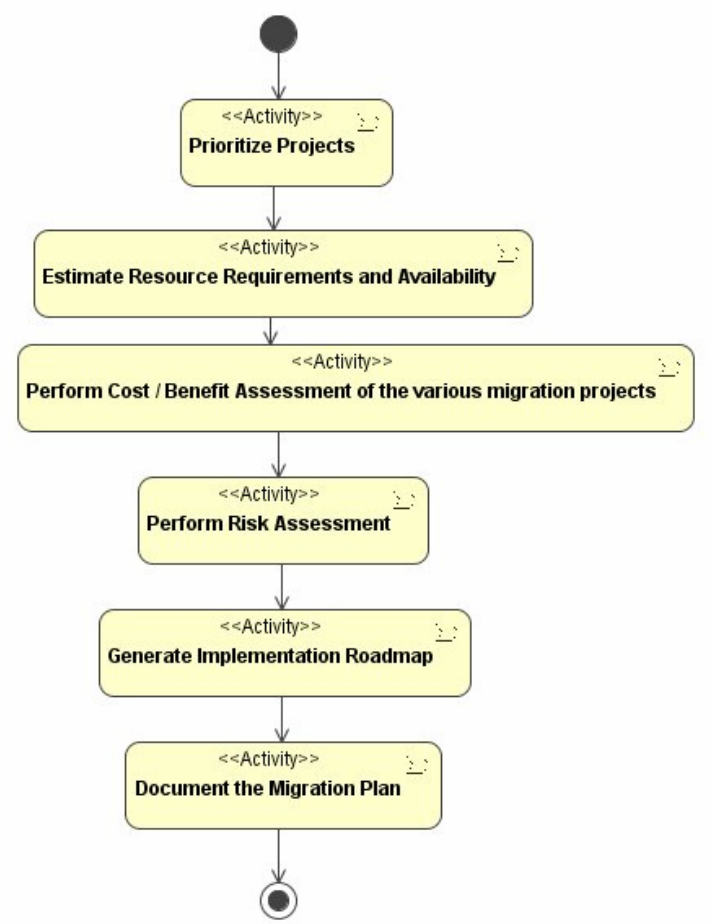

Figure 30: Migration Planning Workflow

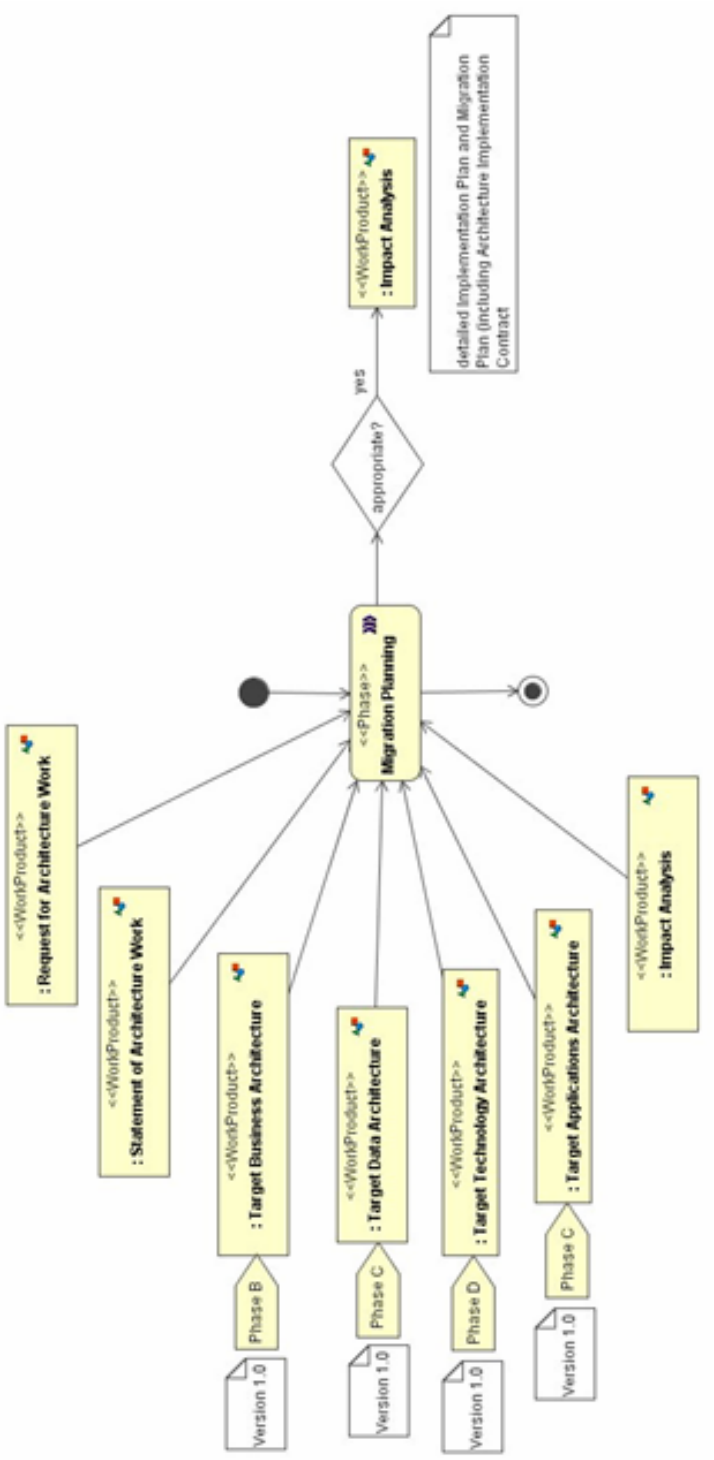

Figure 31: Work Product Inputs and Outputs to Migration Planning

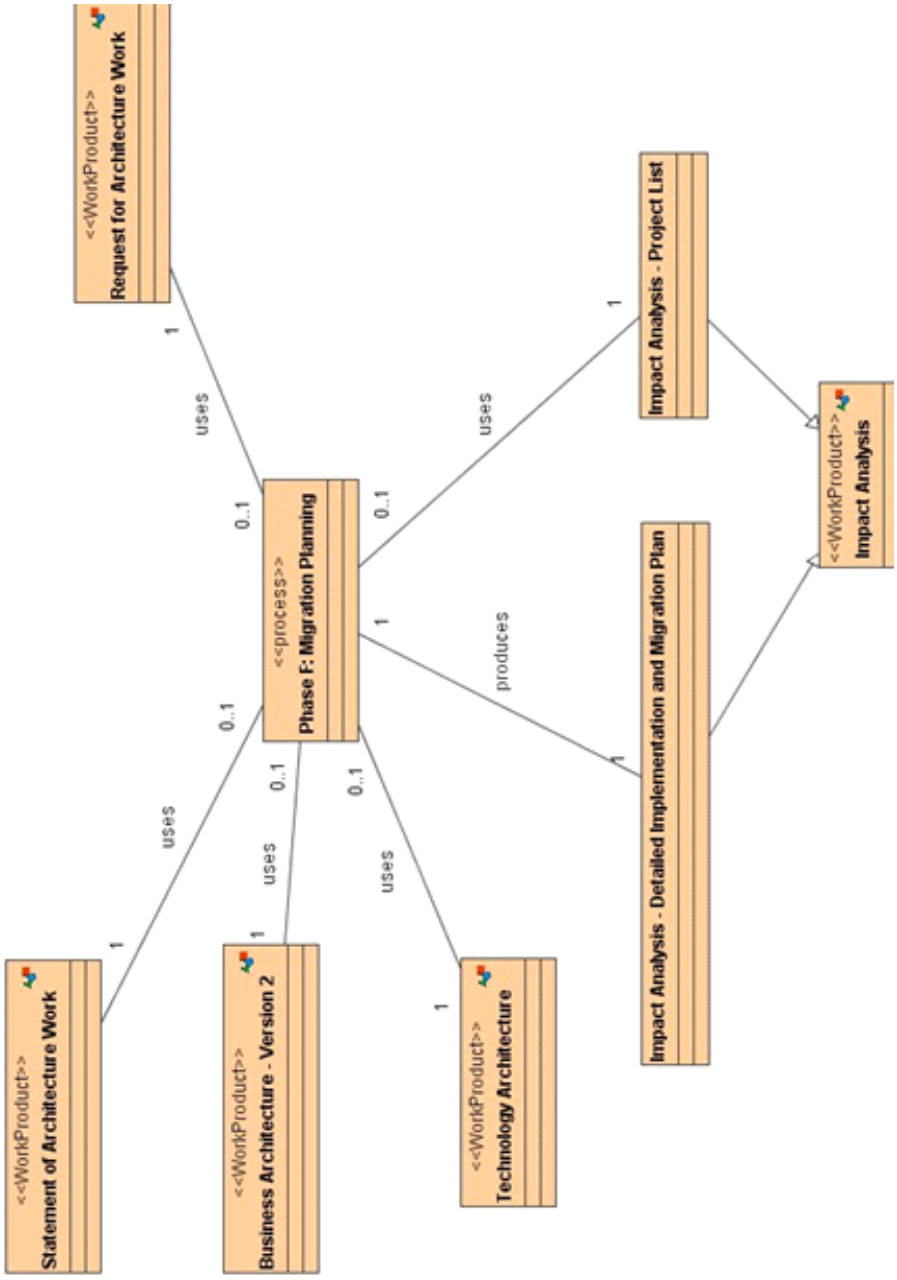

Figure 32: Migration Planning Work Product Relationships

Phase G: Implementation Governance

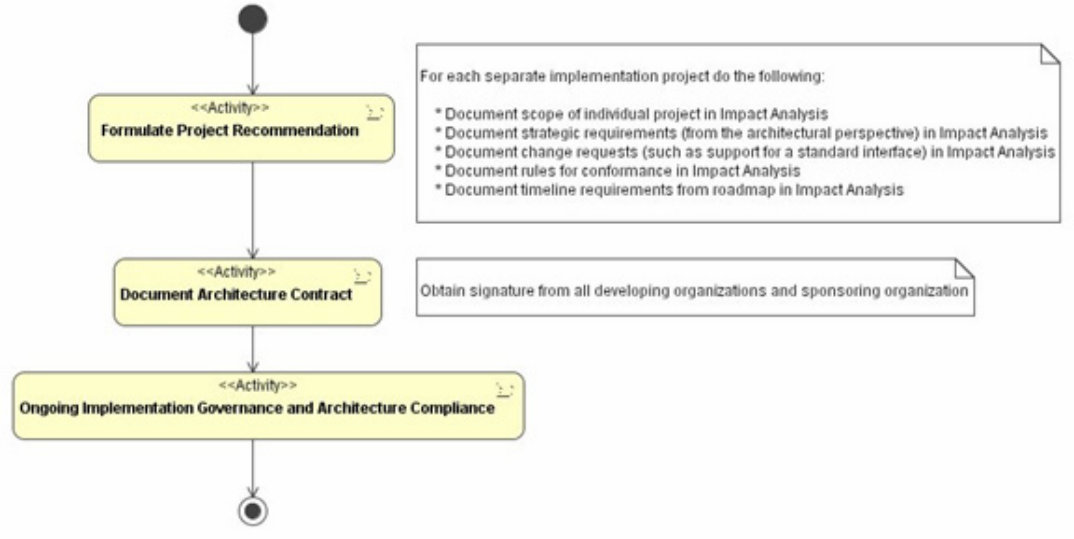

Figure 33: Implementation Governance Workflow

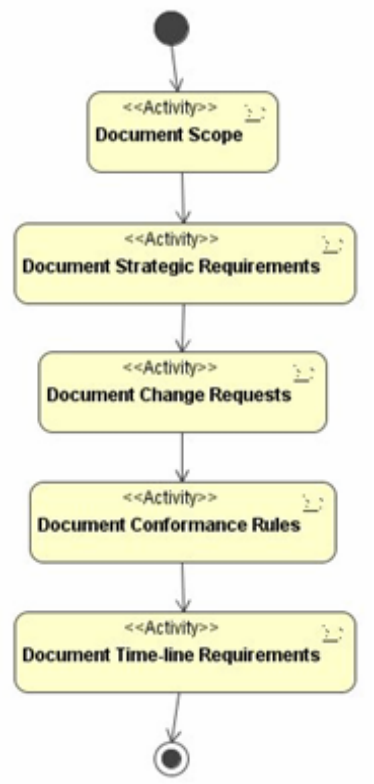

Figure 34: Step 1 – Formulate Project Recommendation Workflow

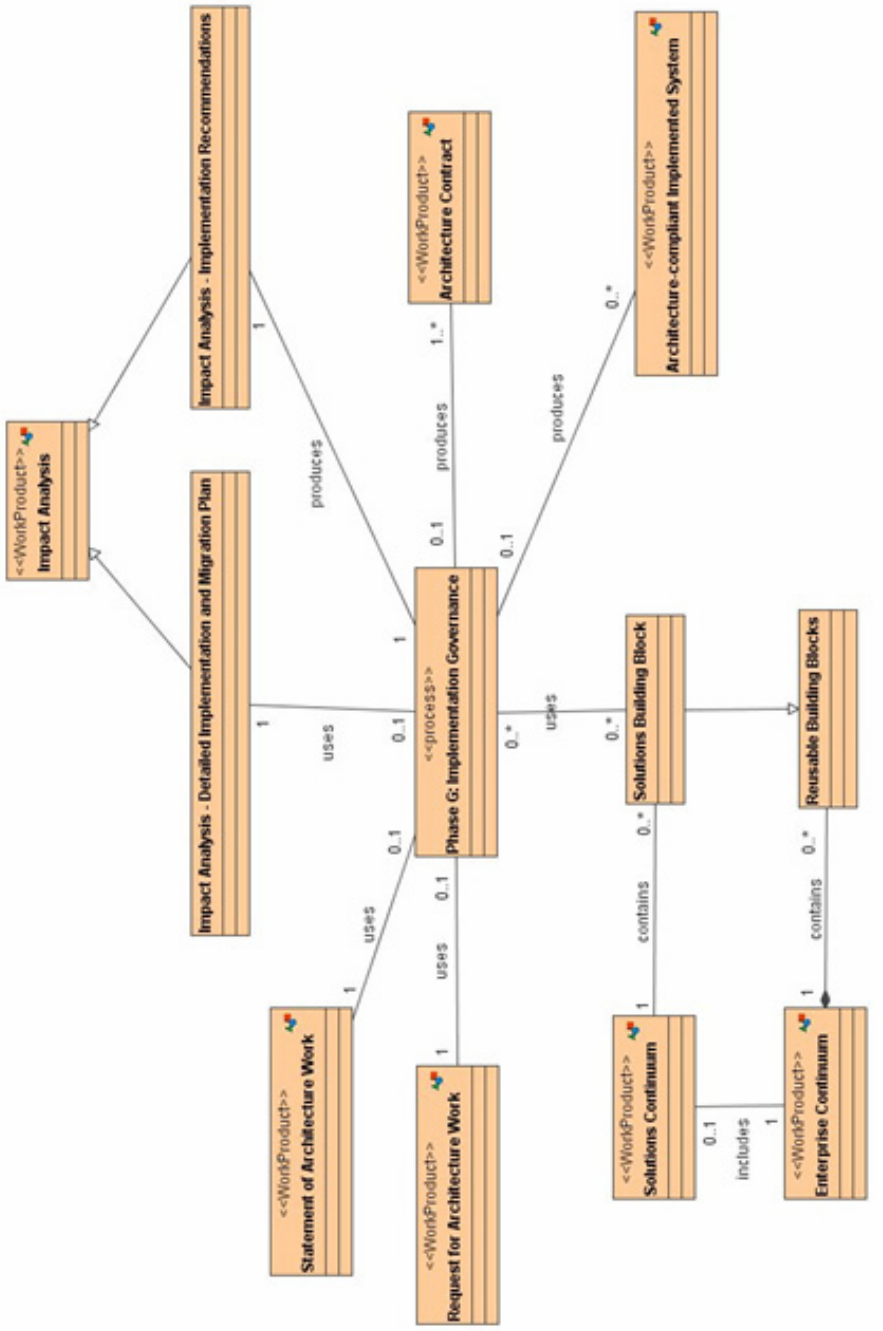

Figure 35: Work Product Inputs and Outputs to Implementation Governance

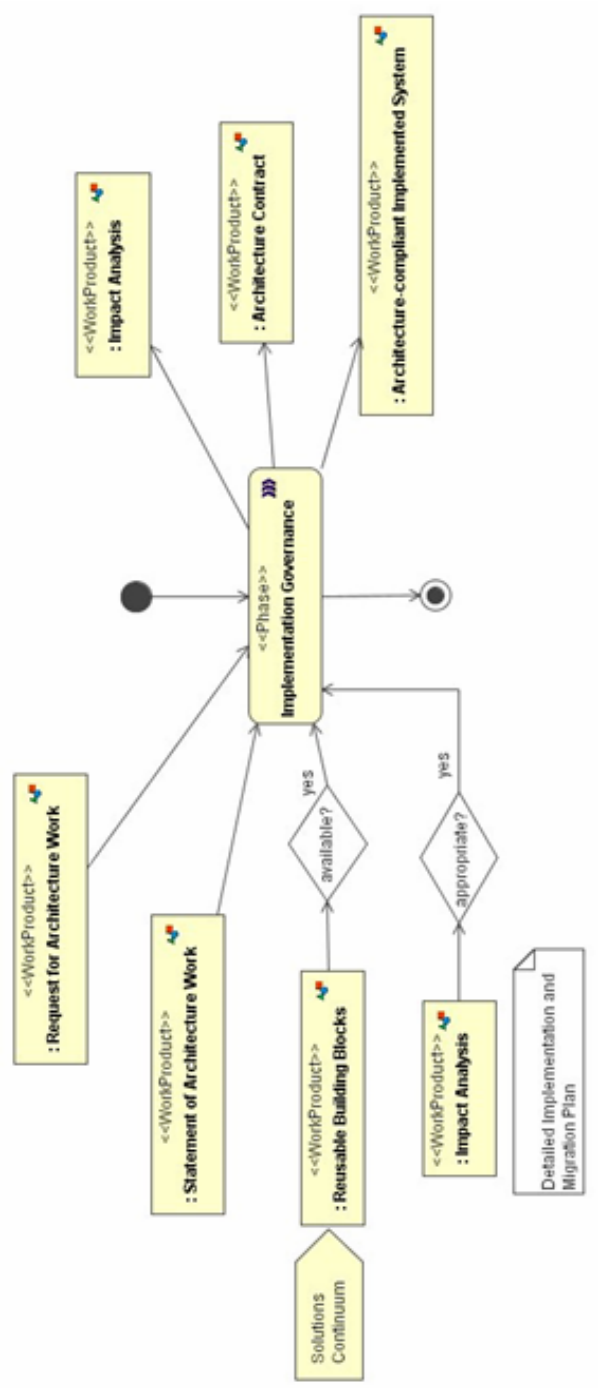

Figure 36: Implementation Governance Work Product Relationships

Phase H: Architecture Change Management

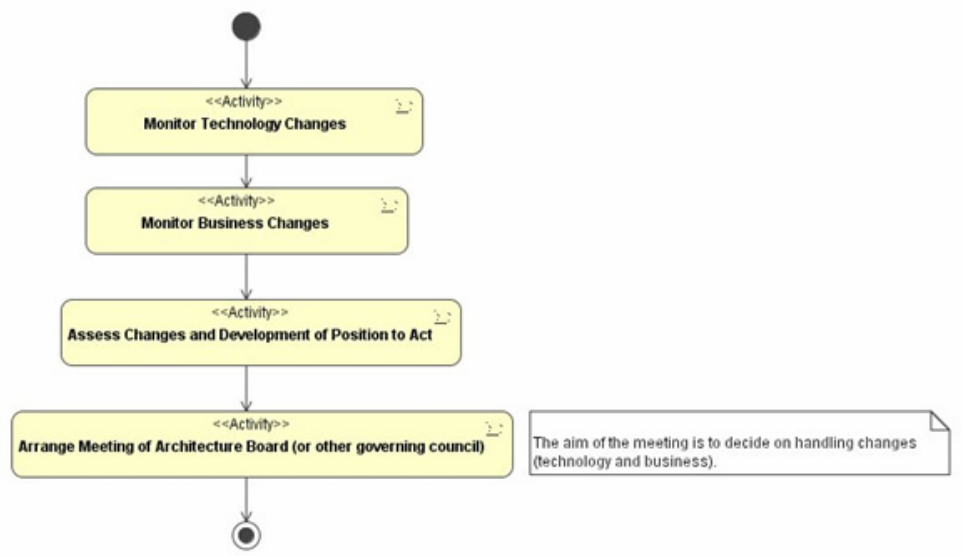

Figure 37: Architecture Change Management Workflow

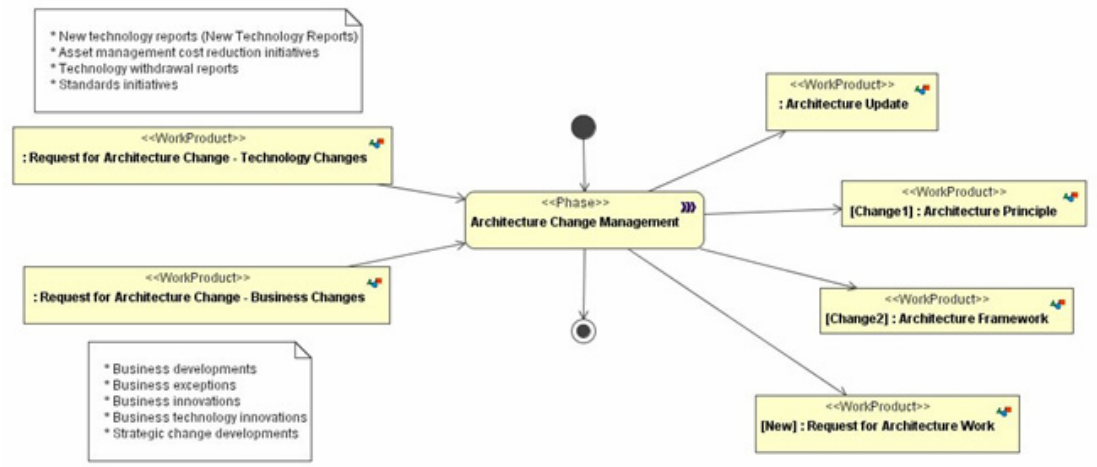

Figure 38: Work Product Inputs and Outputs to Architecture Change Management

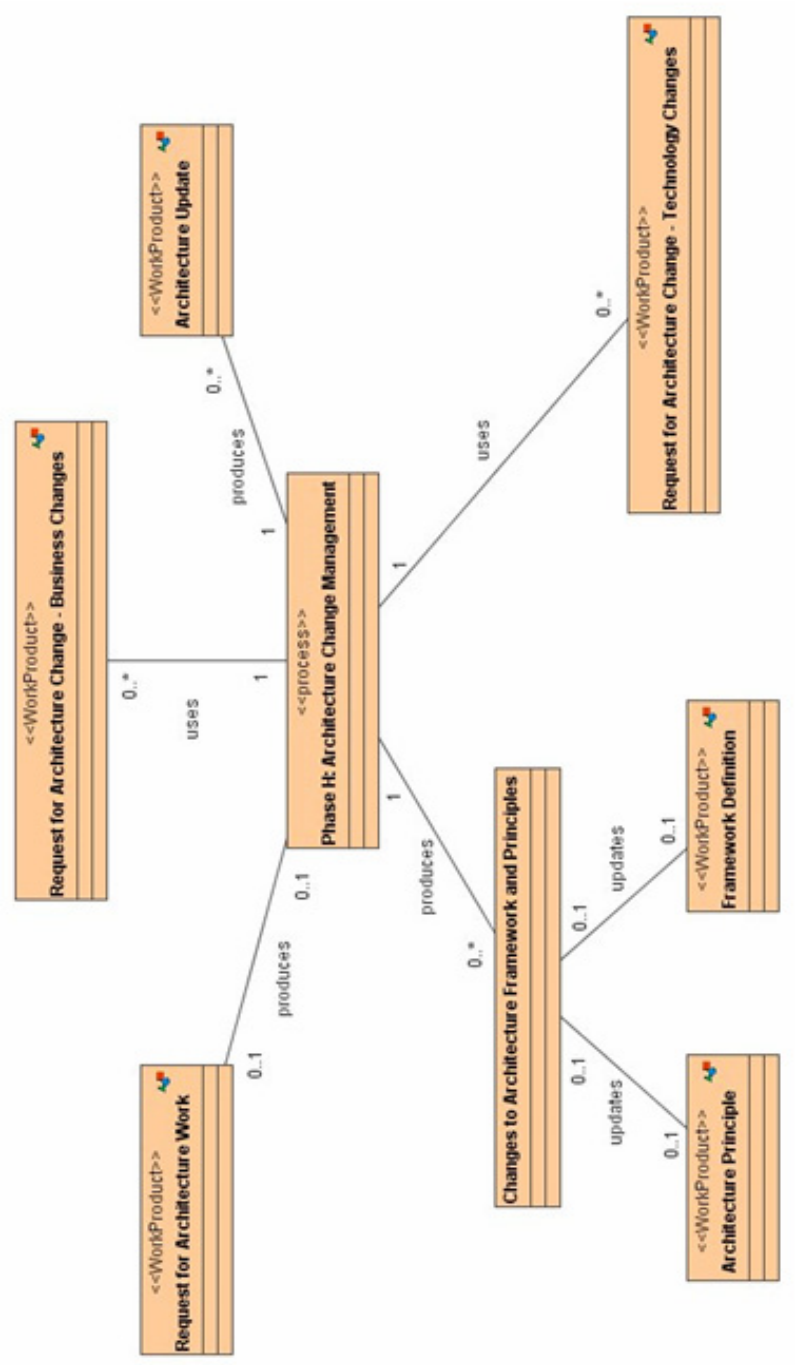

Figure 39: Architecture Change Management Work Product Relationships

Requirements Management

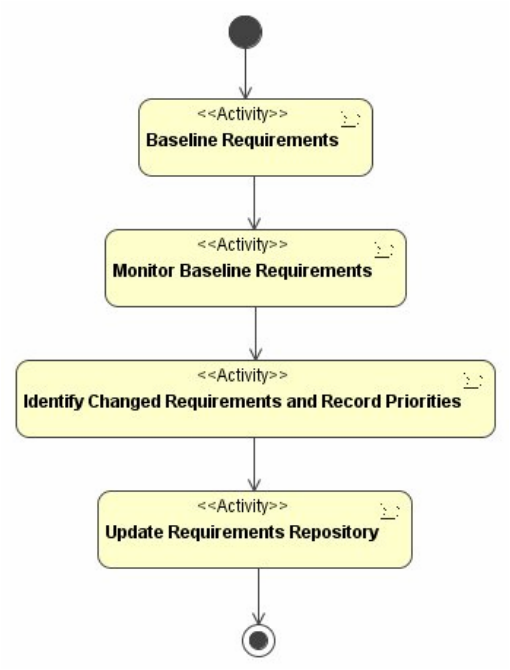

Figure 40: Requirements Management Workflow

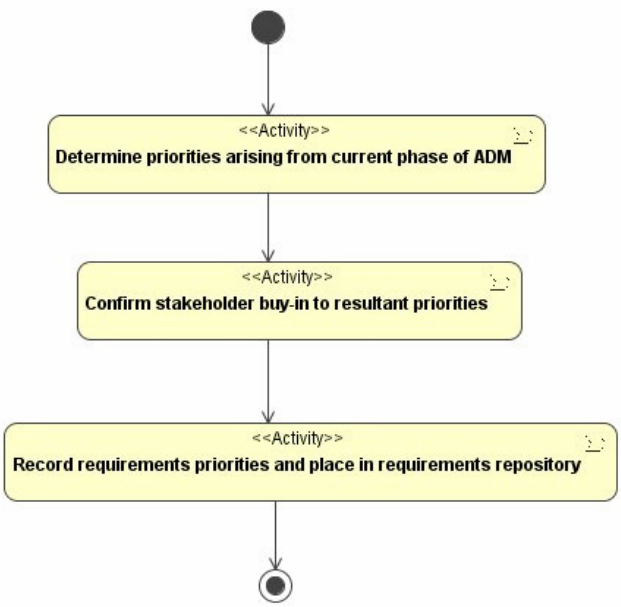

Figure 41: Step 1 – Baseline Requirements Workflow

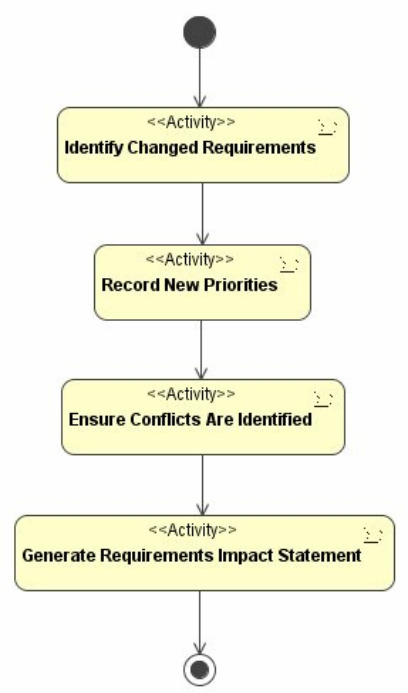

Figure 42: Step 3 – Identify Changed Requirements Workflow

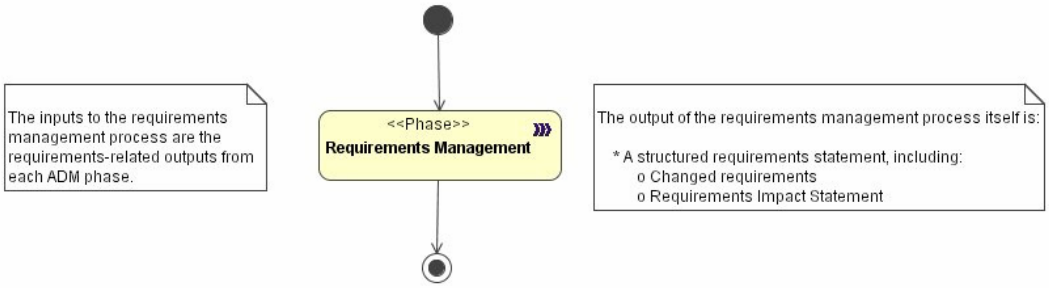

Figure 43: Work Product Inputs and Outputs to Requirements Management

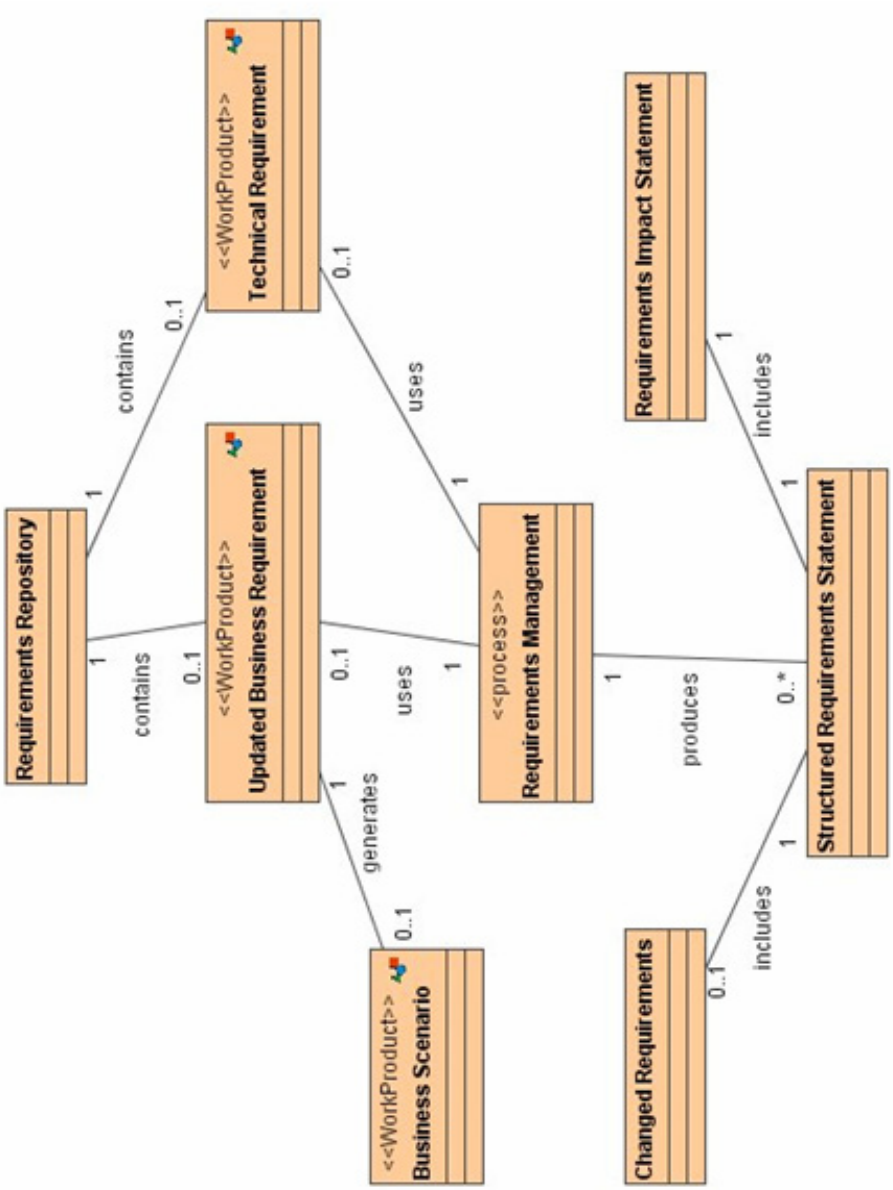

Figure 44: Requirements Management Work Product Relationships

Appendix C: TEAMS Modeling of ADM Phases A-D

Phase A: Architecture Vision

The following table defines the elements of OMG specifications that the TEAMS Consortium chose to represent each of the output work products from TOGAF ADM Phase A.

Phase A: Outputs	Phase A: OMG Representation
Request for Architecture Work Approved Statement of Architecture Work/ Project Definition, including in particular: Scope and constraints Refined statements of Business Principles, Business Goals, and Strategic Drivers Architecture Principles Architecture Vision & Business Scenarios, including: – Business Baseline Version 1 – Technical Baseline Version 1 – Business Architecture Version 1 – Technical Architecture Version 1 Enterprise Continuum	Approved Statement of Architecture Work: text, or UML::Class Diagram Scope and constraints – SysML::Requirement BMM::Business Policy, BMM::Business Goal, BMM::Assessment, BMM::Business Policy Architecture Vision & Business Scenarios including: – UML::Communications Diagram – UML::Communications Diagram – SysML::Block Definition Diagram (Torpedo)

Table 1: Mapping of TEAMS-Specific Phase A Work Products to OMG Specifications

TEAMS architecture vision is "To develop a common technical architecture for torpedo modeling and simulation, including methodologies, tools, standards, and building blocks to build interoperable components, compose simulations quickly at reduced cost, and to support concept assessment, software development, test and evaluation of systems, training, and tactics development". The scope of the TEAMS technical architecture for a torpedo simulation is limited to "launch-to-hit". TEAMS' architecture principles include allowing modelers to develop code in their choice of computer language, allowing model implementers to have a choice of platform-specific implementation options, and ensuring standard interface specifications that TEAMS defines for model components are platform and language-independent.

The Request for Architecture Work was provided by the Office of Naval Research (ONR) in the form of Broad Agency Announcement (BAA). Because this was externally driven, it was in the form of a text document, not a particular element of an OMG specification.

TEAMS provided their original Statement of Architecture Work to ONR in the form of a text document. However, because TEAMS felt the TOGAF community could use guidance on how a Statement of Work should be structured, they developed a UML class diagram of a statement of work, shown in Figure 45. Components include contact information from actors – i.e., a submitter and submittee – as well as background on the task, the approach, objectives, issues, deliverables, work breakdown structure, and cost estimate per task.

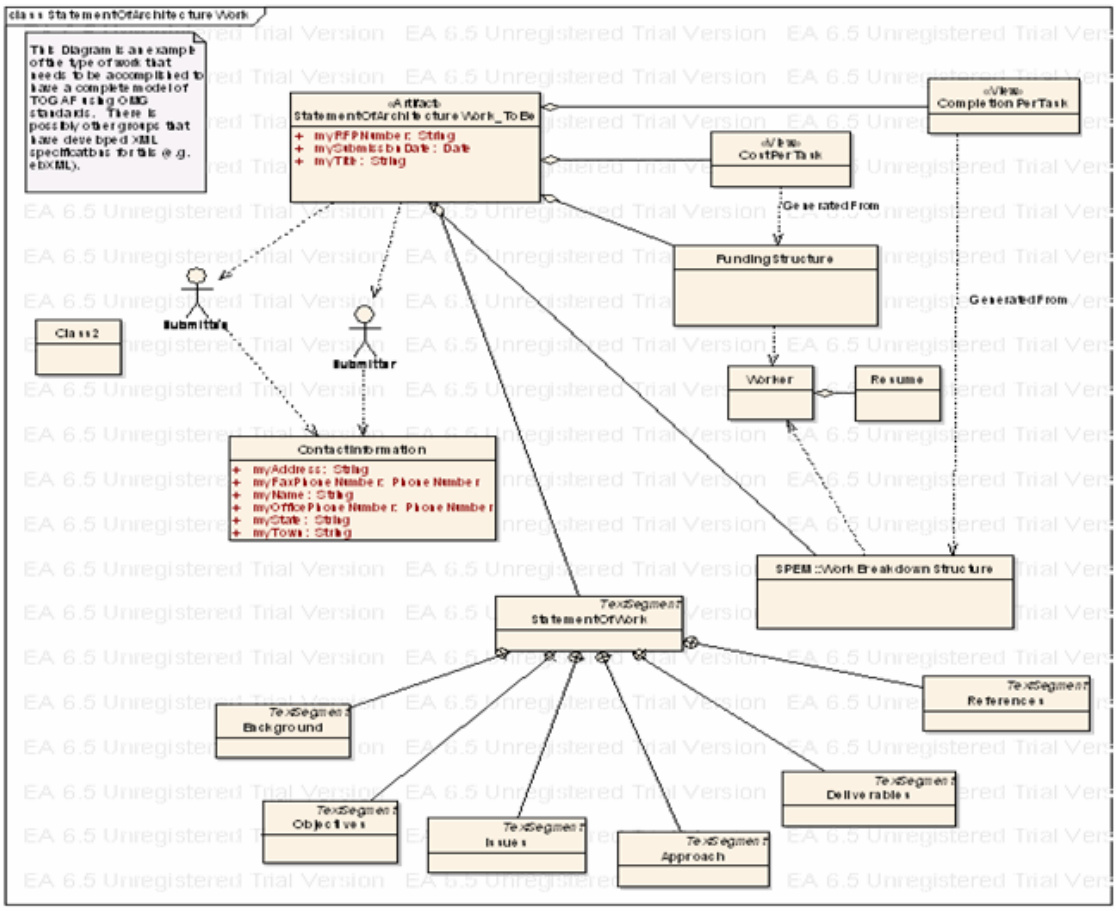

Figure 45: UML Class Diagram representing a Statement of Architecture Work

Scope and constraints of the architecture work are determined by stakeholders, who have different views and requirements. The scope of TEAMS is to standardize components of torpedo modeling and simulation engagement simulations so they can be re-used. Stakeholders include:

- Sponsors, who will save money by supporting this task
- Component developers, who need to standardize their components to "plug" into multiple simulation tools
- Simulation developers, who need to standardize their framework so that components can seamlessly be incorporated into their simulation environment
- Representatives of the Navy fleet, who need to extract accurate output quickly from simulation tools to assess how to invest in future technology and make military value decisions

Stakeholder views and requirements were captured using SysML Requirements block diagrams. High-level requirements for each of the TEAMS stakeholders are shown in Figure 46.

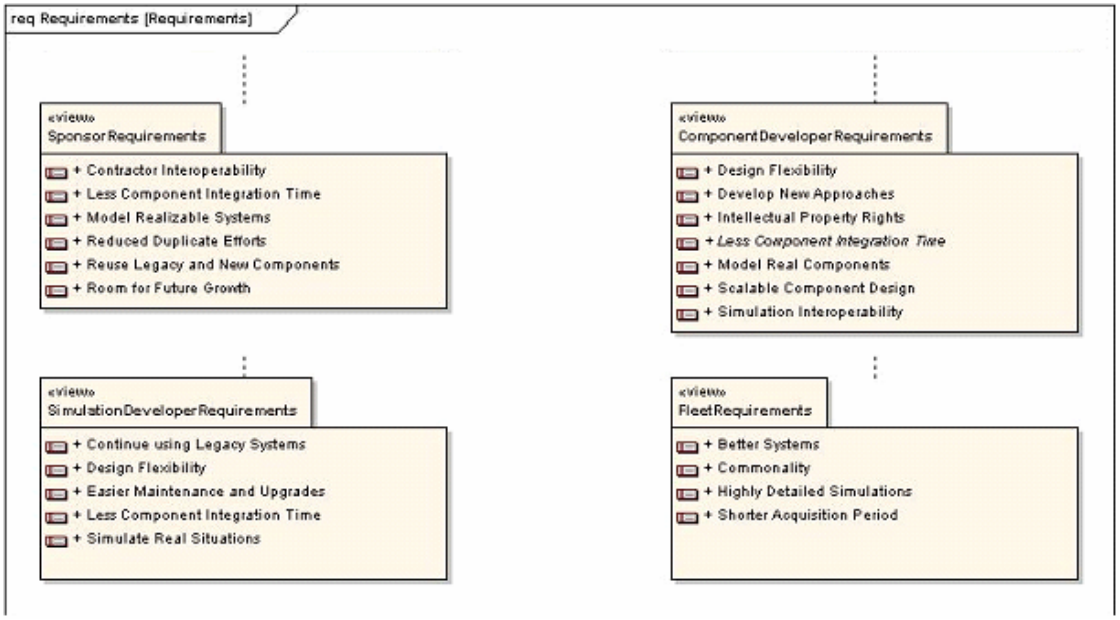

Figure 46: TEAMS Stakeholder Views and Requirements

Refined statements of Business Principles, Business Goals, and Strategic Drivers map directly to components of OMG's Business Motivation Metamodel (BMM). A snippet of the BMM diagram showing the above components is shown in Figure 47.

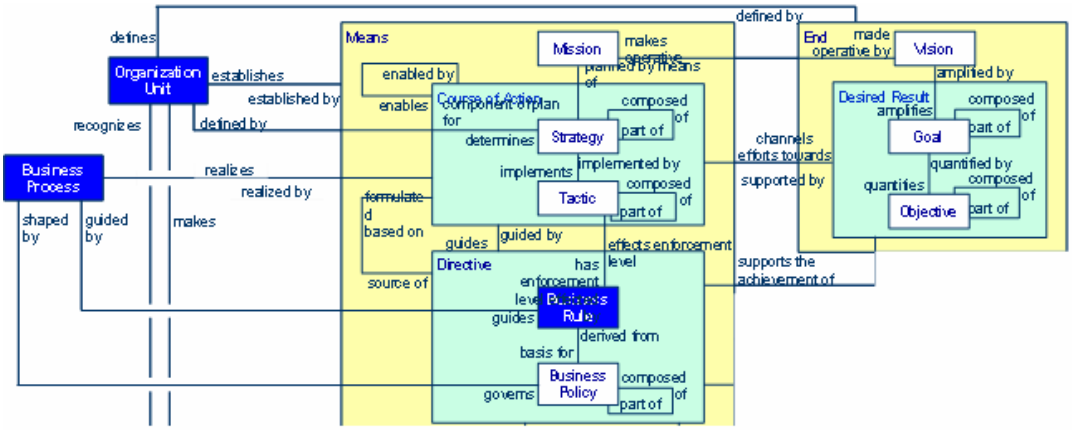

Figure 47: Portion of Business Motivation Metamodel

TEAMS Business and Architecture Principles map directly to BMM::Business Policy, and are listed below.

TEAMS Business Principles:

1. Follow Navy policies for procurement and funding

2. Address IP (Intellectual Property) rights

3. Provide TEAMS as a product to industry, but no industry participation in development

4. Preserve centers of expertise necessary to complete tasks

TEAMS Architecture Principles:

1. Adopt Open Standards, openly arrived at

2. Don't constrain modeling languages

3. Don't constrain PSM implementation

As defined in BMM, Business Policies support the achievement of Business Goals and Objectives.

TEAMS goals and objectives map directly to BMM::Goals and BMM::Objectives. Goals and objectives are listed below.

TEAMS Goals:

1. Demonstrate proof-of-concept of component interoperability (June 2007)

2. Establish TEAMS governance and change management policy (December 2007)

3. Implement Version 1 of Standardized Torpedo M&S framework and ensure it is in use by 2008

TEAMS Objectives:

1. Interoperable simulation components

2. Documented standards and interface requirements

3. Cost-effective process for achieving interoperability and composability among the Navy's M&S tools

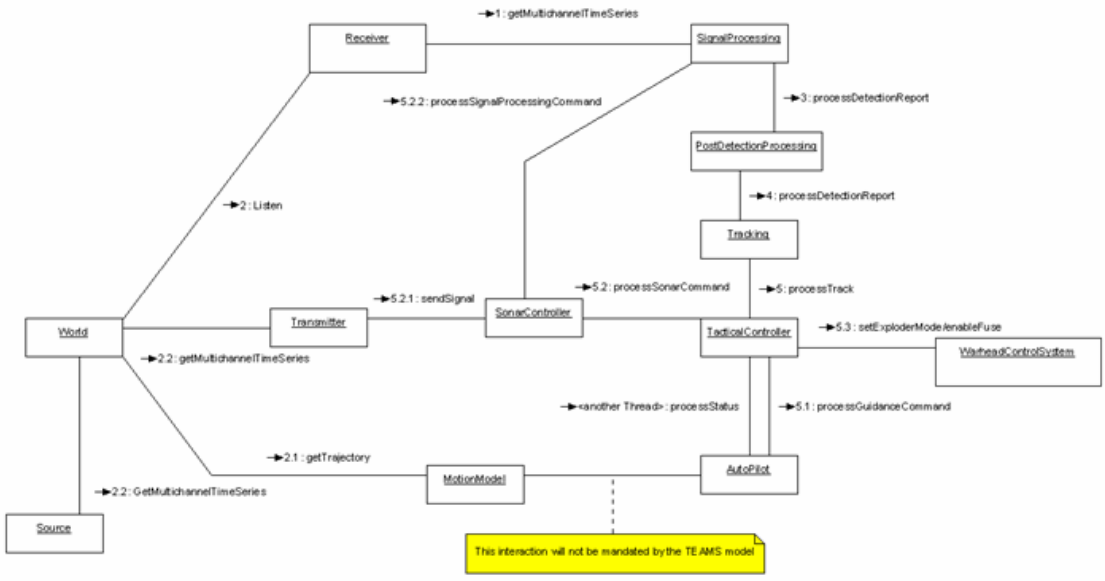

Figure 48: Baseline Simulation Business Architecture

Figure 48 describes the baseline business architecture for torpedo simulation capability. A torpedo must listen to information in a realistic acoustic environment – i.e., "world" – process data, determine whether any potential targets are contained in the data, form reports on which to base tactical decisions, make decisions, and decide how to proceed on the next time step. This is represented as a UML::Communications Diagram.

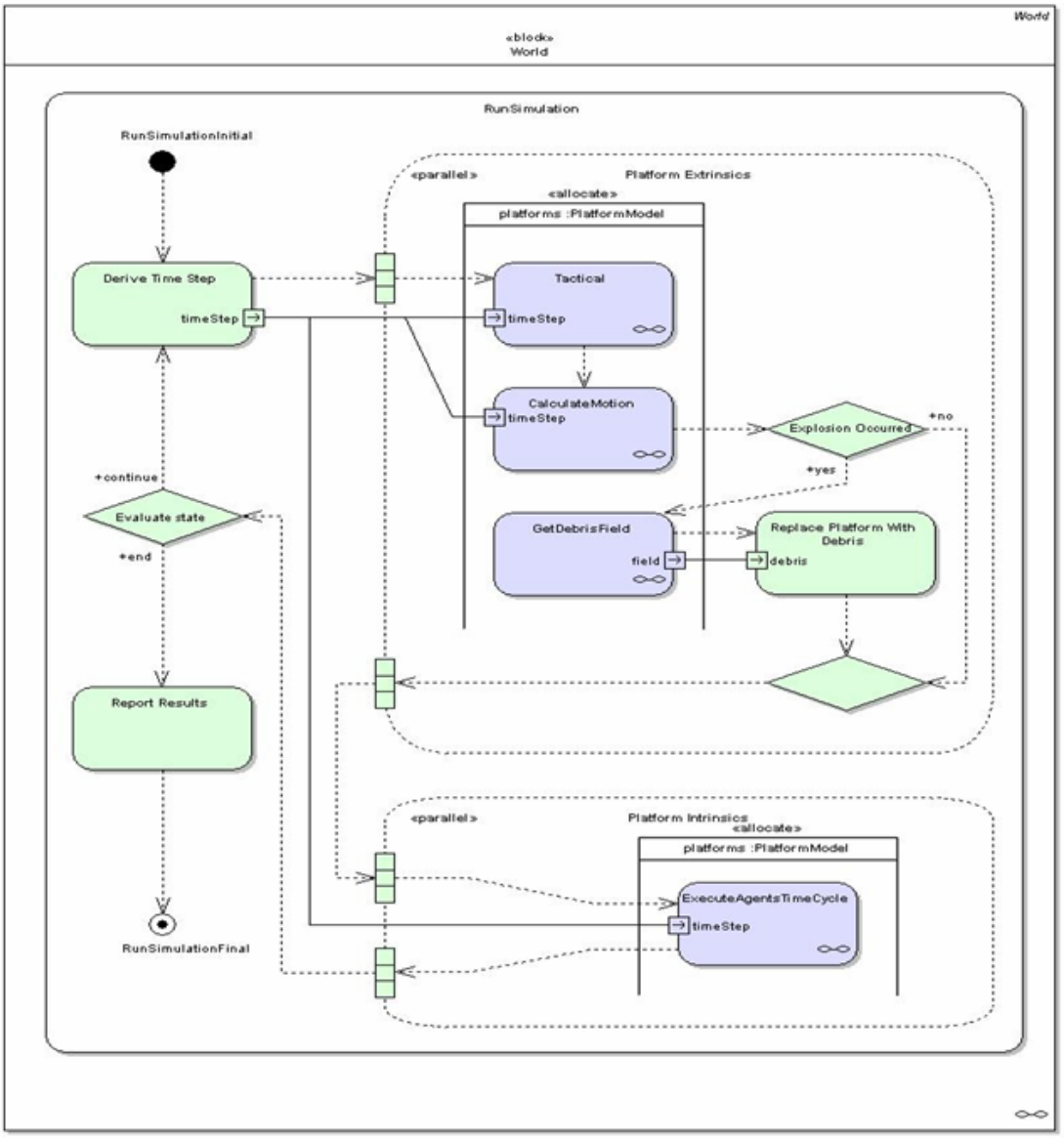

Figure 49: Target Simulation Business Architecture

Figure 49 provides more detail; it is a SysML::Activity Diagram. The baseline simulation architecture in Figure 47 represents a single time step. The target business architecture represents time from launch-to-hit, and encompasses multiple platforms/torpedoes interacting over time. This sets the stage for defining Business Processes and Services for simulation in Phase B, which include supporting a torpedo's ability to be launched, searching for and acquiring a potential target, homing on the correct target, and eventually a kill.

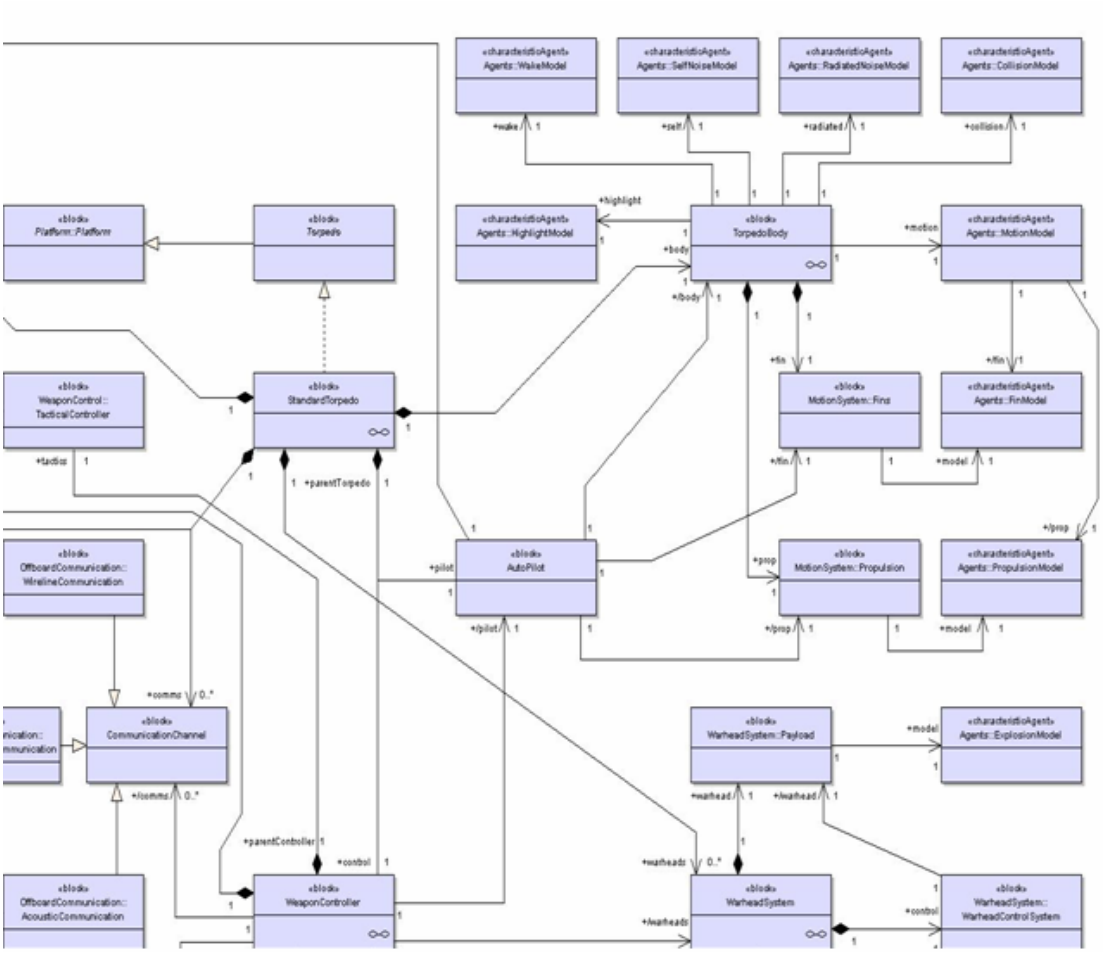

Figure 50: TEAMS Target Technology Architecture

TEAMS leveraged components from several modeling and simulation tools available to the Navy, with the goal of achieving a common architecture framework. TEAMS Target Technology Architecture, an example of some of the common components extracted from multiple simulations tools, is shown in the SysML::Block Definition Diagram in Figure 50.

Phase B: Business Architecture

The following table defines the elements of OMG specifications that the TEAMS Consortium chose to represent each of the output work products from TOGAF ADM Phase B.

Phase B: Outputs	Phase B: OMG Representation
Statement of Architecture Work	SPEM::Work Product
Validated Business Principles, Business Goals, and Strategic Drivers	BMM::Business Policy, BMM::Business Goal, BMM:: Assessment
Target Business Architecture, Version 2	Target Business Architecture – BMM, UML (several subcomponents)
Business Baseline, Version 2	Business Baseline, Version 2 – N/A
Views corresponding to the selected viewpoints addressing key stakeholder concerns	Views – UML, BPMN, BPDM, OSM, SBVR, BMM, ITPMF, MOF
Gap analysis results	Vewpoints – QVT
Technical requirements – drivers for the Technical Architecture work	KDM, QVT, MOF versioning
Business Architecture Report	Technical requirements – SysML::Requirement, UML
Updated business requirements	Business Architecture Report – document
	SysML::Requirement, BMM

Table 2: Mapping of TEAMS-Specific Phase B Work Products to OMG Specifications

TOGAF ADM Phase B outputs for Business Architecture include business requirements, views and viewpoints addressing key stakeholder concerns, technical requirements that drive technology architecture work, and a more detailed description of a Target Business Architecture.

TEAMS stakeholders include:

- The US Navy fleet, which uses the actual torpedoes that are being simulated. They realize that simulation is a valuable tool used to evaluate technology that can transition into their actual weapons sooner.
- Sponsors, who must fund organizations with simulation capability to develop and evaluate technology in the most cost-effective way.
- Developers of simulation tools and component model developers, who must play a major role in developing a standardized technology architecture since their tools and models must comply with the standards.

Subcomponents of Target Business Architecture, Version 2 include:

- Organization structure – identifying business locations and relating them to organizational units
- Business goals and objectives – for each organizational unit
- Business functions – a detailed, recursive step involving successive decomposition of major functional areas into sub-functions
- Business services – the services that each enterprise unit provides to its customers, both internally and externally
- Business processes – including measures and deliverables
- Business roles – including development and modification of skills requirements

- Correlation of organization and functions – relate business functions to organizational units in the form of a matrix report

TEAMS' organization structure includes a list of all simulation tools development organizations currently used by the Navy to evaluate torpedo performance in a launch-to-hit context. They include the Weapons Analysis Facility Hardware-in-the-loop simulator at NUWCDIVNPT, the Technology Requirements Model digital launch-to-hit simulation at ARL/PSU, the Sonar Simulation Toolset at the Applied Physics Lab of the University of Washington (APL/UW), and Cassandra, a simulation engine used to validate threat torpedo implementations, also at NUWCDIVNPT.

Work products from Phase A focus on business principles, goals, and strategic drivers of the TEAMS Consortium. Figure 51 is a UML object diagram that shows one TEAMS Business Goal: Interoperable Simulation Components as an instance of the Business Goal work product and its traceability relationships to other instances of work products. A TEAMS business driver is the need to re-use diverse legacy simulation content. A business strategy to achieve this goal is to migrate to open standards. This leads to a TEAMS business principle: must use open standards. The business goal of achieving interoperable simulation components also fosters business processes. The TEAMS Consortium must perform Systems Engineering to achieve the business goal, and must implement Architecture Governance to ensure components generated in the systems engineering process conform to TEAMS open standards for interoperability. As a further example, the business process of simulation must support a torpedo's ability to be launched, search for and acquire a potential target, home on the correct target, and eventually kill, within a realistic acoustic environment. These and the remaining business process, procurement, become the basis of the Target Business Architecture.

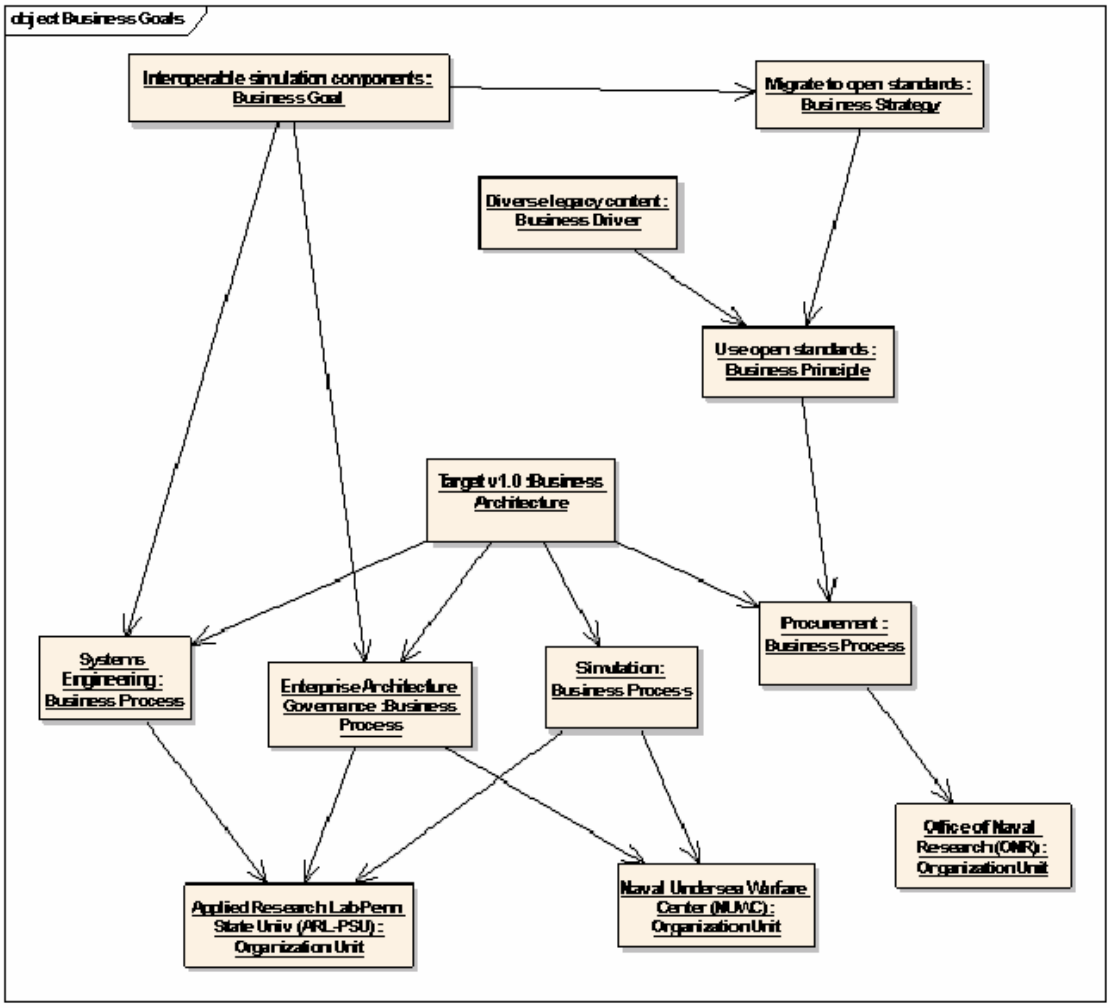

Figure 51: TEAMS Business Goals, Principles, Strategic Drivers, and Processes

The Systems Engineering Business Process can be further expanded to allow new acoustic models or new torpedo components to be integrated into the existing simulation framework in a standard way. Figure 52 is a detailed representation of the "Integrate Simulation Models" business process shown as a UML activity diagram. An External Project Technical Lead requests a non-compliant model to be integrated into a TEAMS-compliant simulation. He provides this component to the TEAMS Consortium, who provides the baseline reference model for this type of component. TEAMS then extracts the Platform-Independent Model (PIM) and Platform-Specific Model (PSM) descriptions for this component. The External Project Technical Lead develops working code to adhere to the TEAMS PIM and PSM, performing gap analysis and modifying the PIM and PSM if necessary. The TEAMS Consortium then receives the new TEAMS component to include into an updated version of the Baseline Reference Model. A simulation developer also receives the modified component to integrate into a simulation tool according to the standard interface definitions that TEAMS provided.

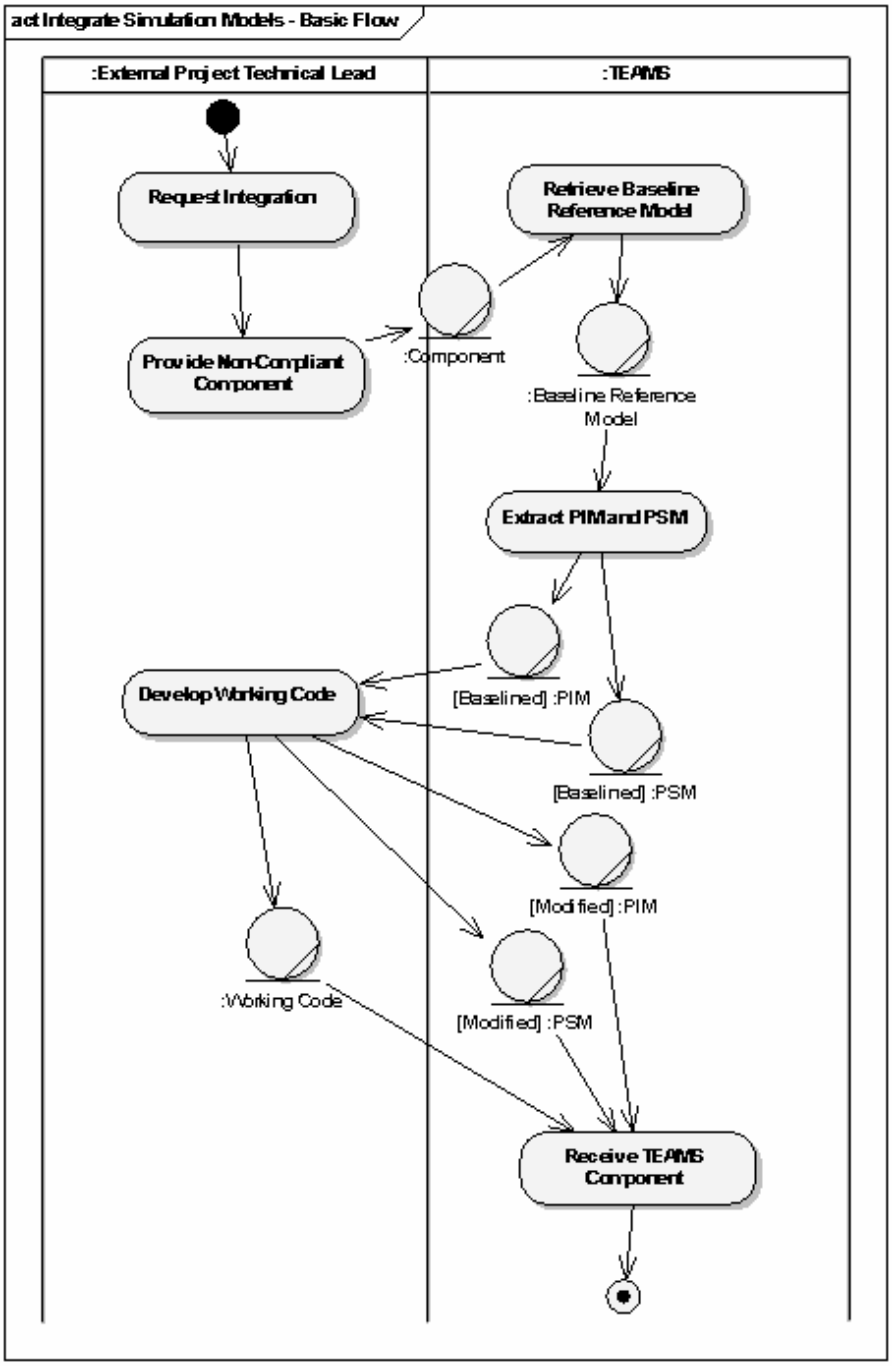

Figure 52: Activity Diagram for TEAMS Systems Engineering Business Process

Phase C: Information Services Architecture

The following table defines the elements of OMG specifications that the TEAMS Consortium chose to represent each of the output work products from TOGAF ADM Phase C.

Phase C: Outputs	Phase C: OMG Representation
Updated Statement of Architecture Work Target Data Architecture Target Applications Architecture Data Architecture Views Applications Architecture Views Data Architecture Report Applications Architecture Report Gap Analysis Impact Analysis Updated Business Requirements	UML::Class Diagram Target Data Architecture – UML, SysML (several subcomponents) Target Applications Architecture – UML, SysML (several subcomponents) Views – UML, BPMN, BPDM, OSM, SBVR, BMM, ITPMF, MOF (Vewpoints – QVT) Data Architecture Report – document Applications Architecture Report – document KDM, QVT, MOF versioning SysML::Requirement, BMM

Table 3: Mapping of TEAMS-Specific Phase C Work Products to OMG Specifications

TOGAF Phase C, Information Systems Architecture, is subdivided into two areas: Data Architecture and Applications Architecture. Data Architecture defines how data flows. Applications Architecture defines who will use the data, what a user or application requires, and where and when it is required. Detailed descriptions of data and application architecture work products represented in elements of OMG specifications are described below.

Phase C: Data Architecture

The following table defines the elements of OMG specifications that the TEAMS Consortium chose to represent each of the output work products from TOGAF ADM Phase C's Data Architecture.

Phase C: Data Outputs	Phase C: OMG Representation
Target Data Architecture – Conceptual Data Model – Logical Data Model – Data Management Process Model – Data Entity/Business Function Matrix – Data Interoperability Requirements	Target Data Architecture – UML::class or SysML::Block Definition Diagram – SysML::Block Definition Diagram – UML::class diagram – UML:: or SysML::Activity diagram – SysML::Requirement
Data Architecture Views – Dissemination – Lifecycle – Security – Model Management	Data Architecture Views – document – UML::state machine diagram – QVT, MOF Versioning – QVT, MOF Versioning
Data Architecture Report	Data Architecture Report – document
Gap Analysis	KDM, QVT, MOF versioning
Impact Analysis Updated Business Requirements	Updated Business Requirements – SysML::Requirement

Table 4: Mapping of TEAMS-Specific Phase C Data Architecture Work Products to OMG Specifications

Output work products for a Target Data Architecture include a Business Data Model, Logical Data Model, Data Management Process Model, Data Interoperability Requirements, and different views and viewpoints such as data dissemination, data lifecycle, data security, and data model management.

TEAMS' Business Data Model for a simulation is a data model of the game board; i.e., the "world" in which a simulation engagement unfolds. It must support the business process of launch, acquire, home, and kill in a realistic acoustic environment. TEAMS represented this as a *conceptual data model* using the SysML Block Definition diagram shown in Figure 53.

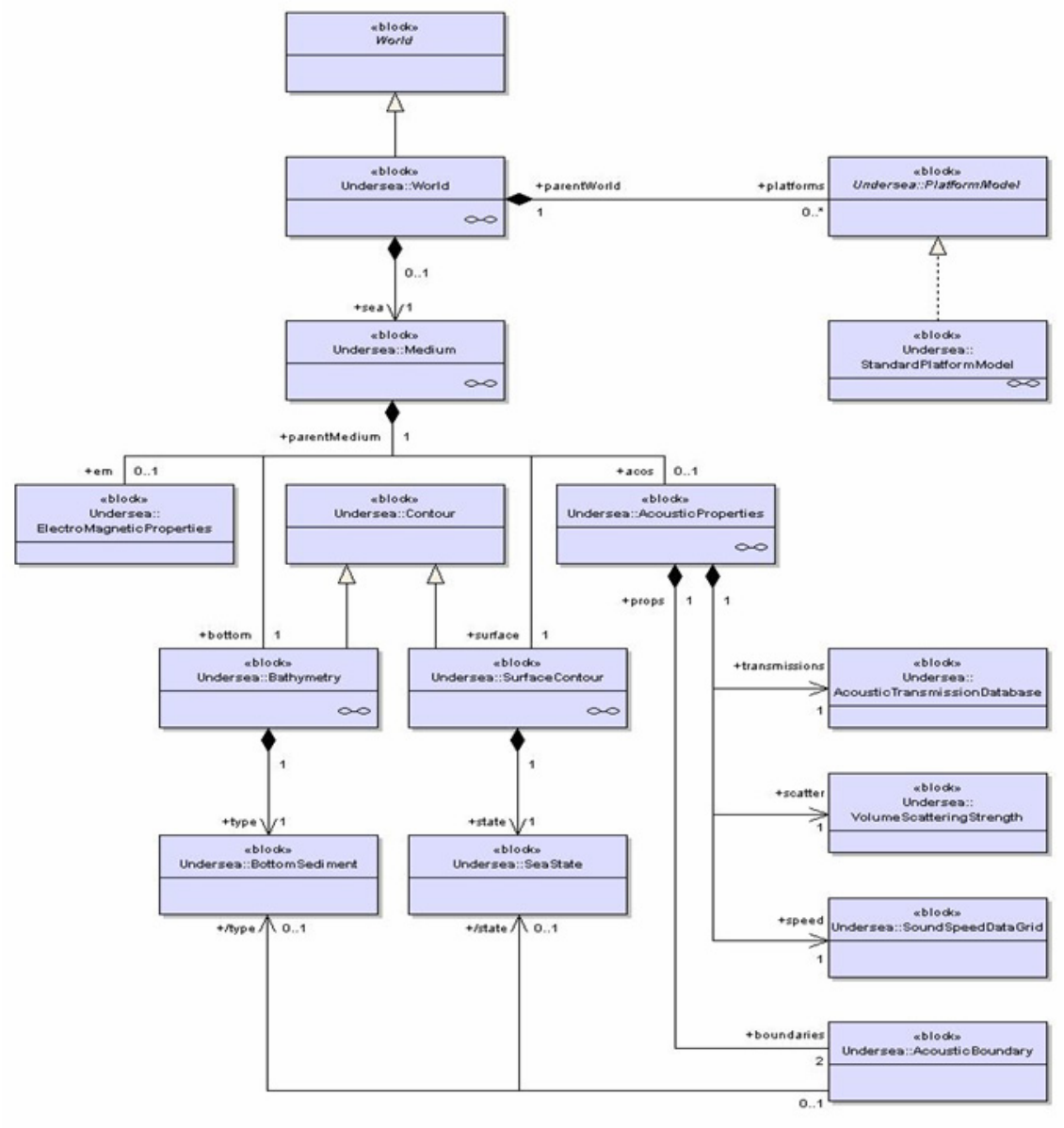

Figure 53: TEAMS Conceptual Data Model for Simulation "World"

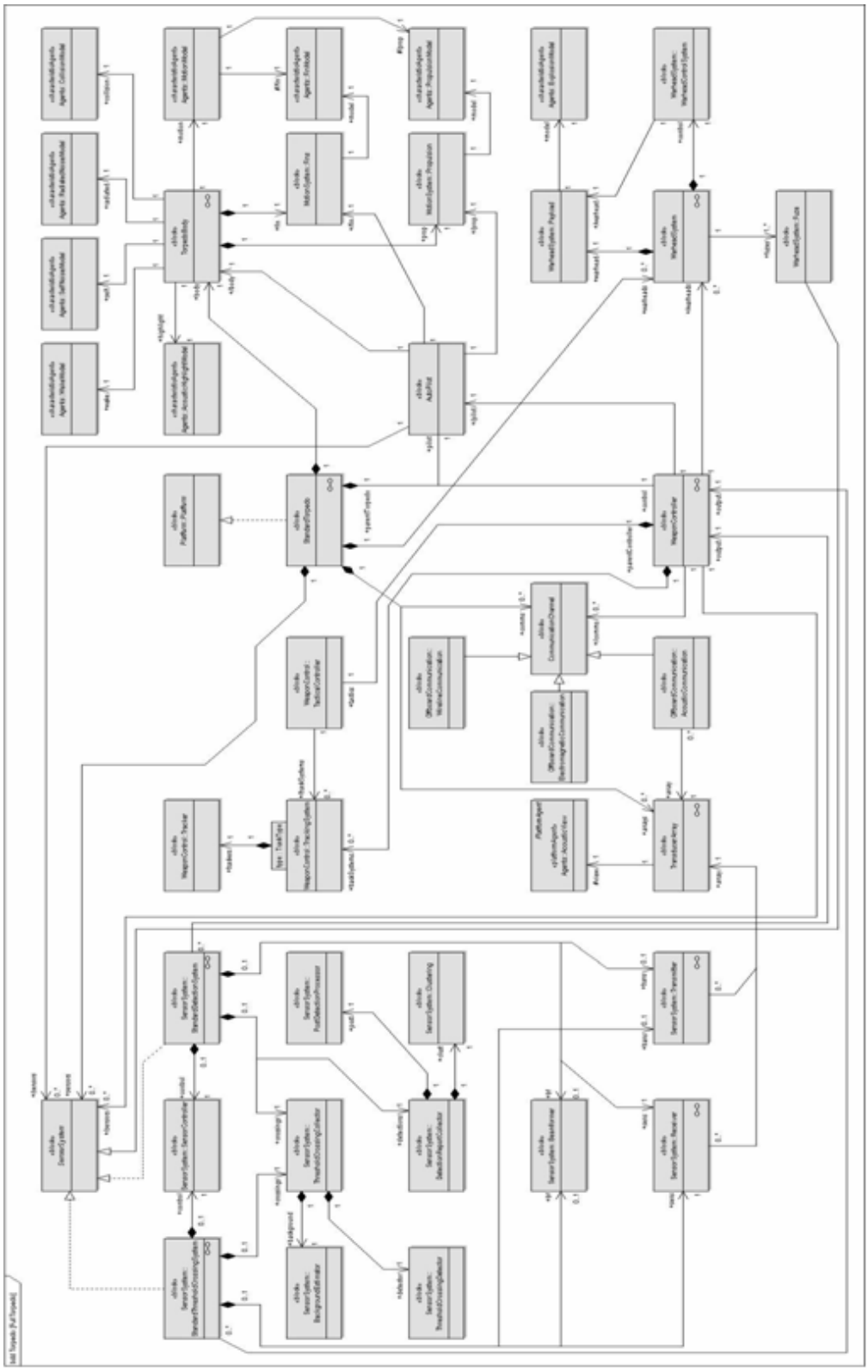

Figure 54: TEAMS Logical Data Model: SysML Block Definition Diagram for Torpedo System

TEAMS' logical data model is the component description of a torpedo, and how it interacts with a simulated environment. TEAMS captured this using a SysML block definition diagram for a torpedo system model, shown in Figure 54.

The TEAMS data management process model describes how simulations instantiate, use, and eventually deactivate model components they are using. TEAMS has defined a preliminary process, using a factory to construct components with the defined parameter list requested by the simulation tool. This is represented by the UML class diagram shown in Figure C-12.

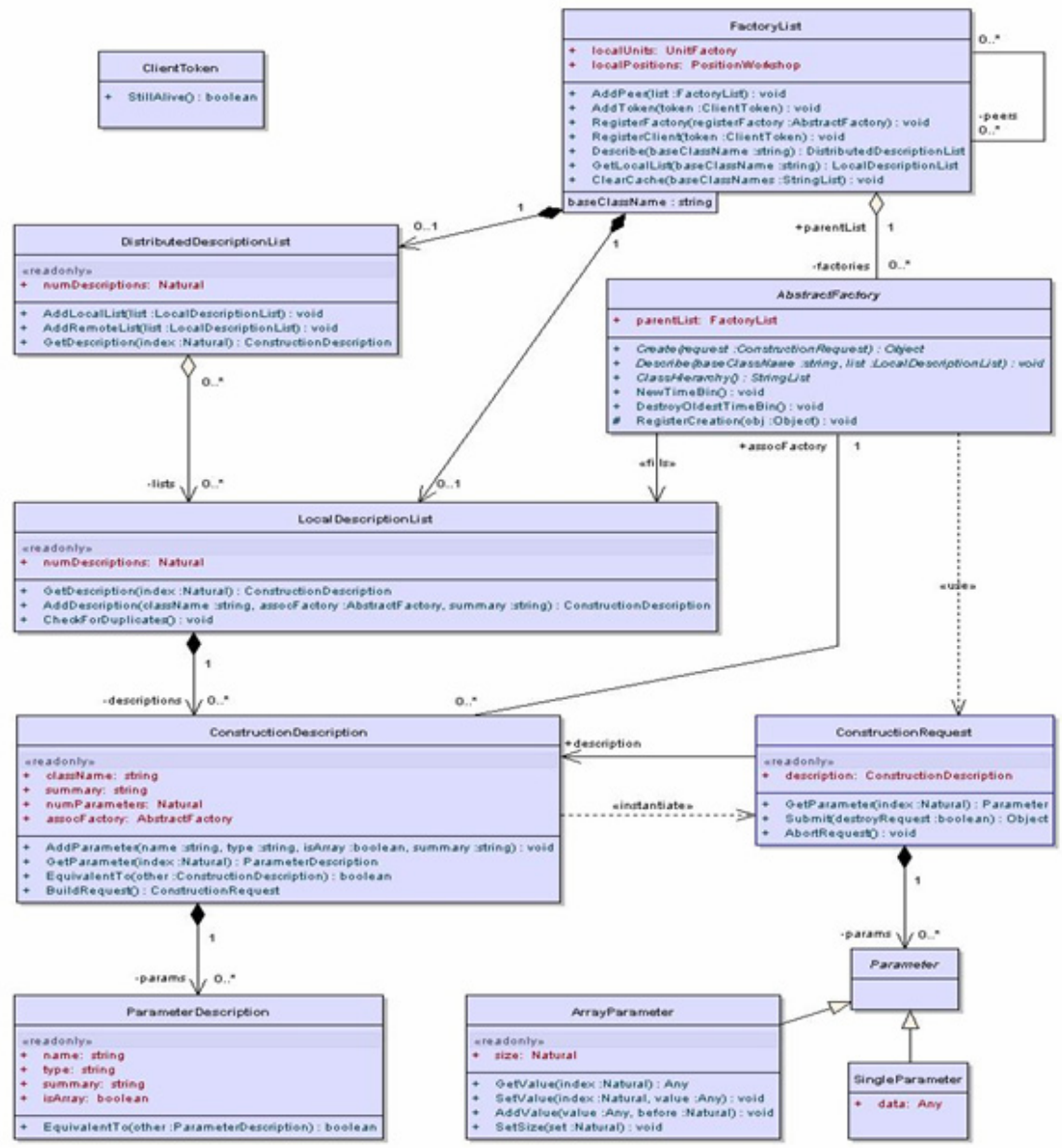

Figure 55: TEAMS Data Management Process Model

TEAMS data interoperability requirements were captured in a SysML requirements block diagram, shown in Figure 56.

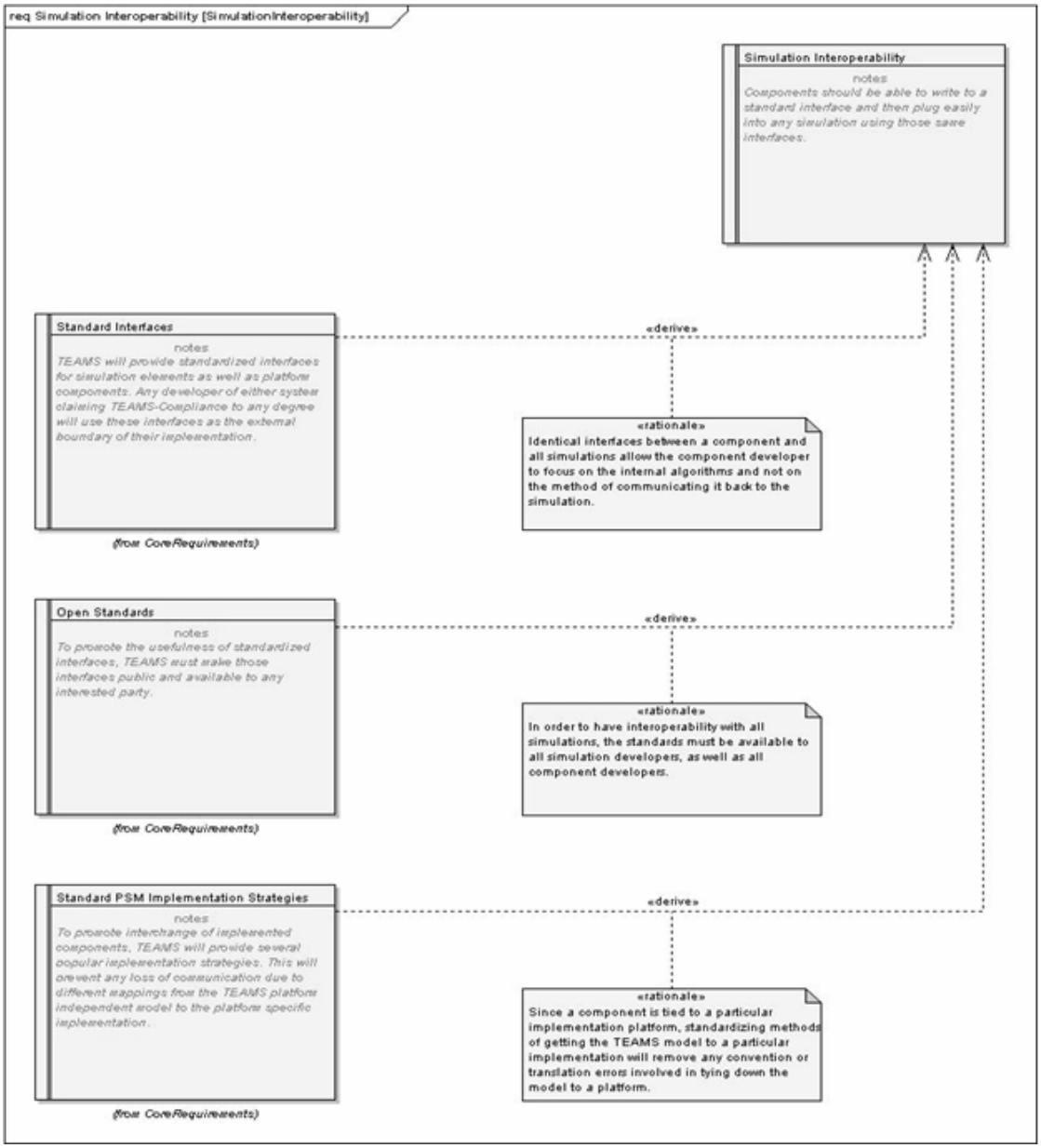

Figure 56: TEAMS Data Interoperability Requirements: SysML Requirements Block Diagram

Phase C: Applications Architecture

The following table defines the elements of OMG specifications that the TEAMS Consortium chose to represent each of the output work products from TOGAF ADM Phase A.

Phase C: Applications Outputs	Phase C: OMG Representation
Target Applications Architecture – Place Systems Model – Process Systems Model – Time Systems Model – People Systems Model – App. Interoperability Requirements Application Architecture Views – Common Applications Services – Applications Interoperability – Applications Information – Applications User Locations Applications Architecture Report Gap Analysis Impact Analysis Updated Business Requirements	Target Applications Architecture – SysML::internal Block Definition Diagram – UML:: or SysML::Activity diagram – UML:: or SysML::Activity diagram – SysML::Requirement Application Architecture Views – UML::component or SysML::Block Definition Diagram – UML::component or SysML::Internal Block Definition Diagram – SysML::Block Definition Diagram – QVT, MOF Versioning KDM, QVT, MOF versioning Updated Business Requirements – SysML::Requirement

Table 5: Mapping of TEAMS-Specific Phase C Applications Architecture Work Products to OMG Specifications

Outputs for a Target Applications Architecture include a place systems model, process systems model, time systems model, and application interoperability requirements, as well as views and viewpoints for Applications Services, Interoperability, and Information Flow.

TEAMS used UML and SysML activity diagrams to represent the Process and Time Systems Models for its Target Application Architecture. Their activity diagram for a simulation loop represents who is playing on the game board, and who controls the time step for all players in the simulated engagement. Figure 57 shows a SysML activity diagram to represent this.

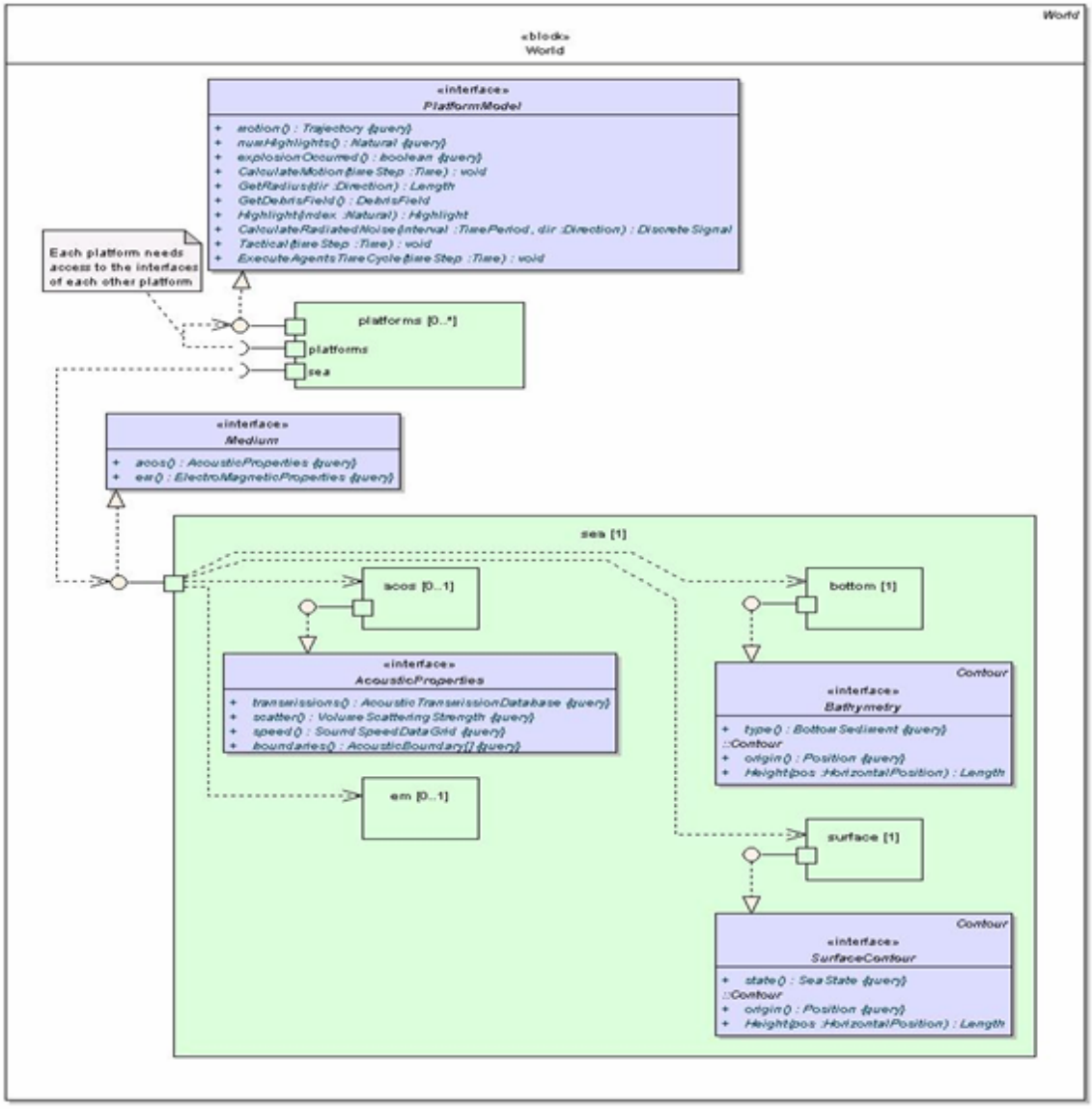

Figure 57: TEAMS Process and Time Systems Models: Simulation Activity Diagram

TEAMS represented the actual game board, the Place Systems Model, by a SysML internal block diagram for multiple platforms.

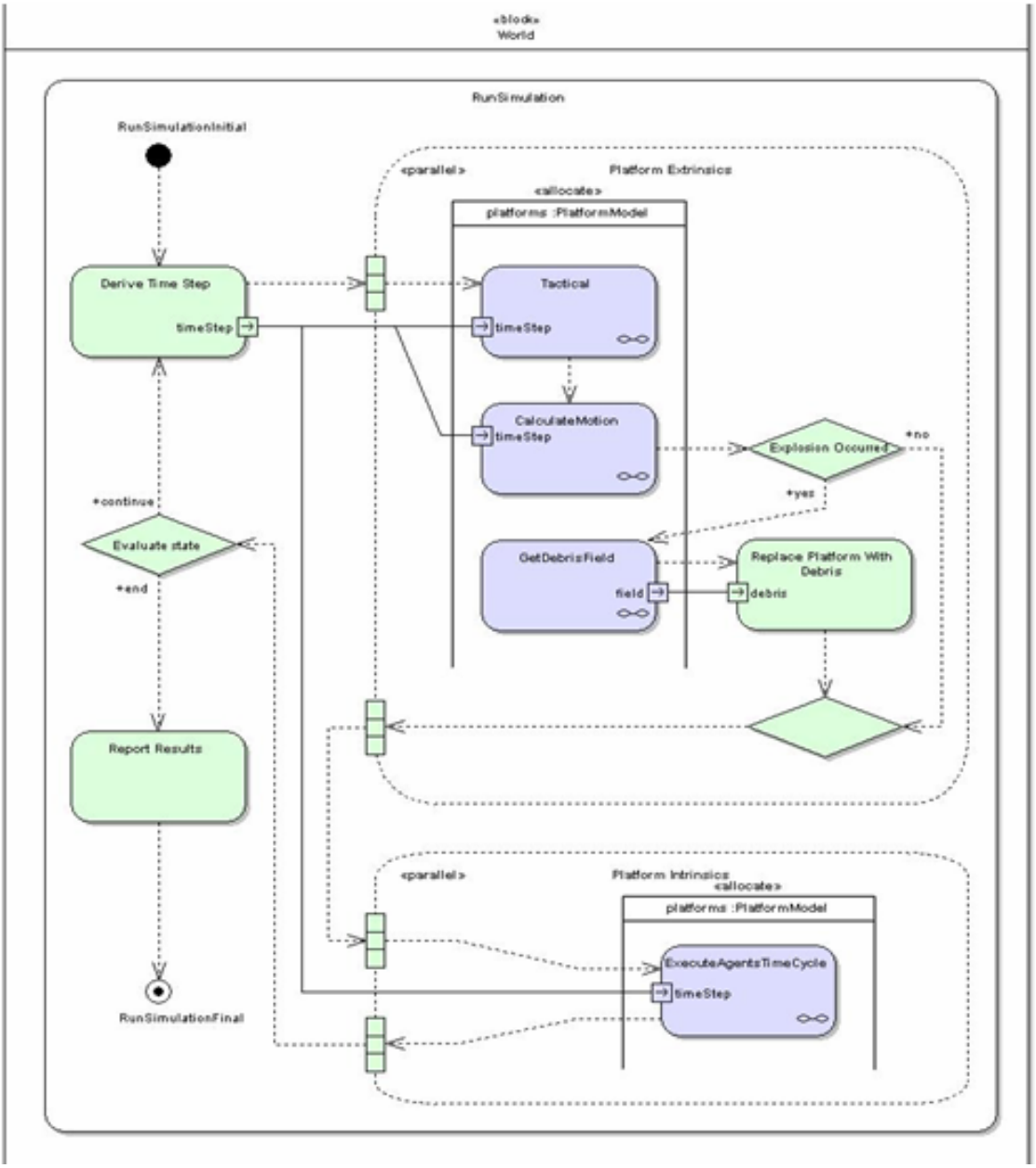

Figure 58: Teams Place System Model – Simulation World Represented by SysML::Internal Block Definition Diagram

Two views and viewpoints of an Applications Architecture for a torpedo system, Applications Services and Interoperability Views, can be represented by either a SysML internal block diagram (IBD) or UML component diagram. Figure 59 shows TEAMS' Interoperability View for a torpedo using a SysML IBD. The "balls and sockets" indicate whether components "provide" information (ball) or "receive" information (socket). These serve as initial interface definitions of standard wrappers for re-usable software components. They are structured so that a high-level component can be treated as a black box to a developer, but also can be drilled into to extract subcomponents as required. In the TEAMS example, the "black box" is a torpedo model, but subcomponents for a torpedo controller and sonar can also be extracted. The data structures for clustered reports and tracks (trajectories) are represented as "balls" and "sockets" in these subcomponents.

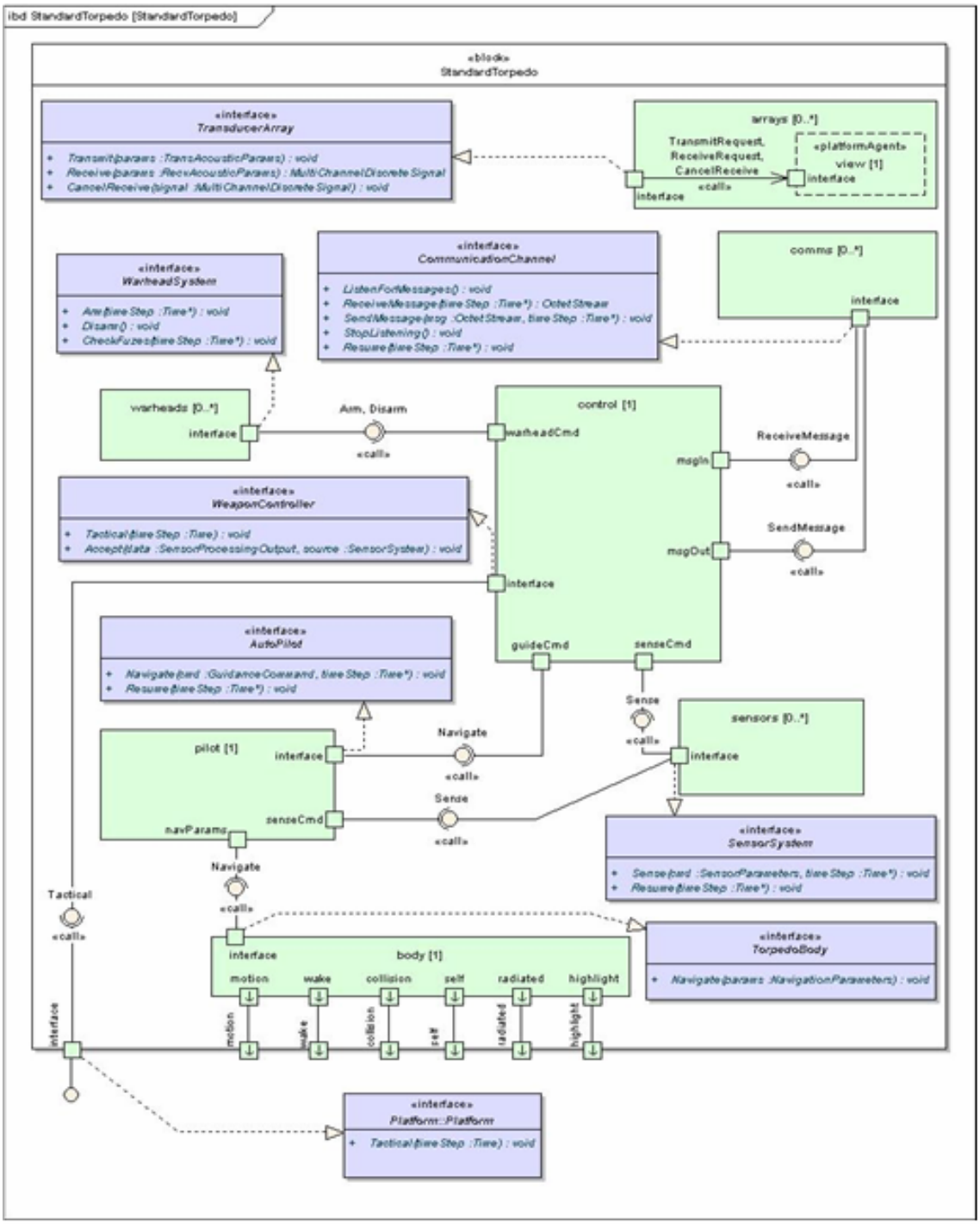

Figure 59: TEAMS Interoperability View: SysML Internal Block Diagram of a Torpedo System

Figure 60 shows an example of a TEAMS Applications Information View for sonar processing. A UML class diagram defines value types, methods, and parameters to be exchanged between components when transmitting and receiving acoustic data.

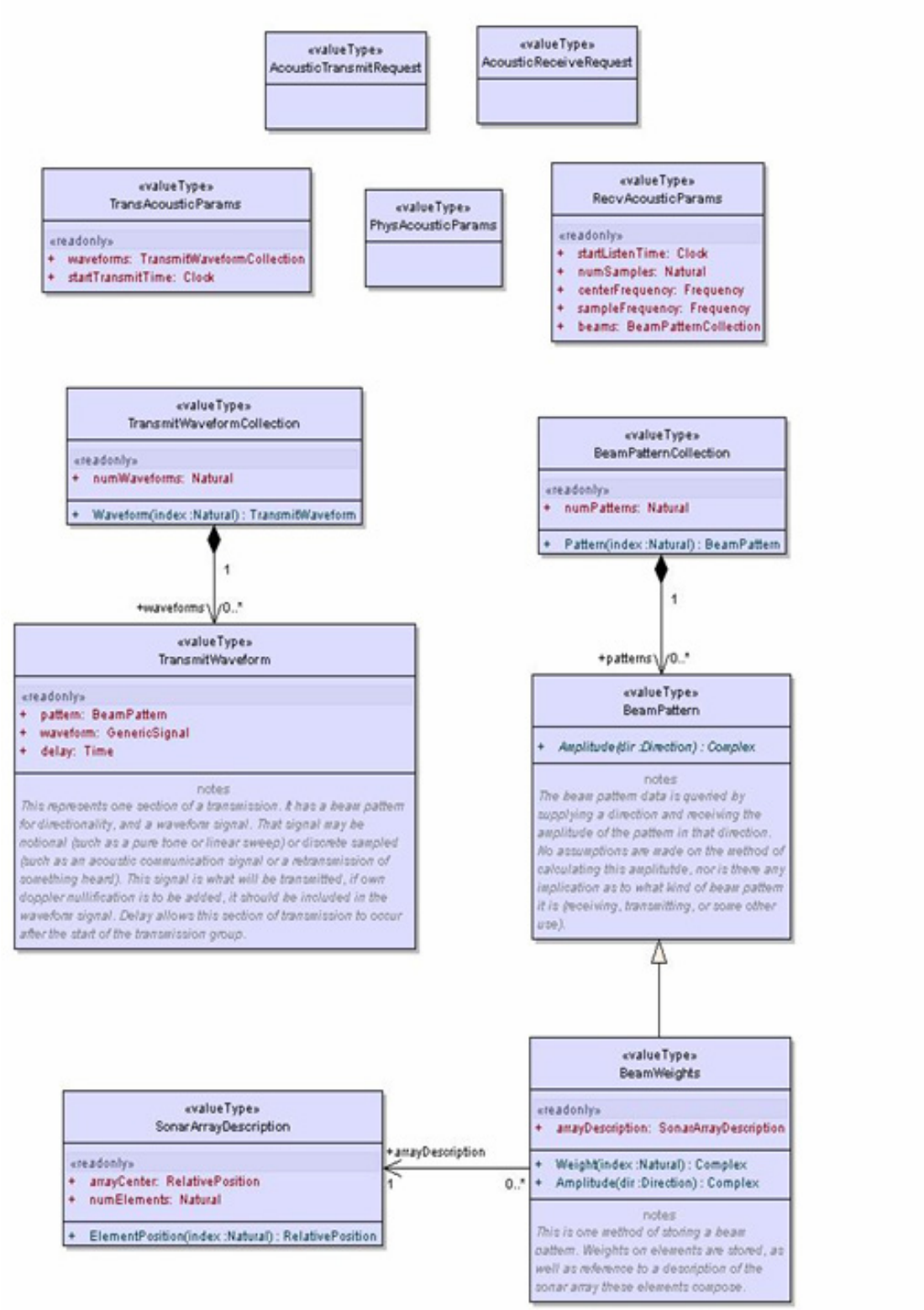

Figure 60: TEAMS Applications Information View for Transmitting and Receiving Acoustic Data, Represented as a UML::Class Diagram

Phase D: Technology Architecture

Finally, TOGAF Phase D outputs for a Technology Architecture include the complete Business Architecture from Phase B, the Data and Applications Architectures from Phase C, architecture principles, requirements traceability, views for computing and hardware, standards to be used, processing constraints, cost constraints, and a gap analysis report. TEAMS' Technology Architecture is the full systems engineering model of a torpedo system, as well as the simulated environment a torpedo model must interact with to satisfy the business requirements for launch-to-hit engagements.

References

ADM	TOGAF Architecture Development Methodology (ADM); see www.opengroup.org/public/arch/p2/p2_intro.htm
ADM & MDA	White Paper: TOGAF ADM & MDA, T. Blevins, J. Spencer, & F. Waskiewicz (2004); see www.opengroup.org/bookstore/catalog/w052.htm
ARL	Applied Research Laboratory (ARL); see www.arl.psu.edu
BMM	OMG Business Motivation Model (BMM); see www.omg.org/technology/documents/br_pm_spec_catalog.htm#BMM
BPMN	OMG Business Process Management Notation (BMN); see www.omg.org/technology/documents/br_pm_spec_catalog.htm#BPMN
DoDAF	Department of Defense Architecture Framework (DoDAF); see www.dod.mil/cio-nii/cio/earch.shtml
EAI	OMG UML Profile for Enterprise Application Integration (EAI); see www.omg.org/technology/documents/profile_catalog.htm#UML_for_EAI
EDOC	OMG UML Profile for Enterprise Distributed Object Computing (EDOC); see www.omg.org/technology/documents/profile_catalog.htm#UML_for_EDOC
EPF	Eclipse Process Framework (EPF); see www.eclipse.org/epf
IC	Integration Consortium (IC); see www.integrationconsortium.org
ITPMF	OMG IT Portfolio Management Facility (ITPMF); see doc.omg.org/bei/2004-06-07
KDM	OMG Knowledge Discovery Metamodel (KDM): see www.omg.org/technology/documents/modernization_spec_catalog.htm#KDM
MDA	OMG Model Driven Architecture (MDA); see www.omg.org/mda
MOF	OMG Meta Object Facility (MOF): see www.omg.org/technology/documents/modeling_spec_catalog.htm#MOF
NUWC	Naval Undersea Warfare Center (NUWC); see www.npt.nuwc.navy.mil
ODM	OMG Ontology Definition Metamodel (ODM); see www.omg.org/technology/documents/modeling_spec_catalog.htm#ODM
OMG	Object Management Group (OMG); see www.omg.org
QVT	OMG MOF Query/Views/Transformations (QVT); see www.omg.org/technology/documents/modeling_spec_catalog.htm#MOF_QVT
RAS	OMG Reusable Asset Specification (RAS); see www.omg.org/technology/documents/modeling_spec_catalog.htm#RAS

SBVR	OMG Semantics of Business Vocabulary and Business Rules (SBVR); see www.omg.org/technology/documents/br_pm_spec_catalog.htm#SBVR
SPEM	OMG Software Process Engineering Metamodel (SPEM); see www.omg.org/technology/documents/modeling_spec_catalog.htm#SPEM
SySML	OMG System Modeling Language (SysML); see www.omg.org/technology/documents/profile_catalog.htm#SysML
TEAMS	Torpedo Enterprise Advanced Modeling & Simulation (TEAMS); see uswteams.arl.psu.edu
The Open Group	See www.opengroup.org
TOGAF	The Open Group Architecture Framework (TOGAF); see www.opengroup.org/togaf
UML	OMG Unified Modeling Language (UML); see www.omg.org/technology/documents/modeling_spec_catalog.htm#UML
XMI	OMG XML Metadata Interchange (XMI); see www.omg.org/technology/documents/modeling_spec_catalog.htm#XMI

Synergy Project Team Members

Without the active participation of numerous individuals, the Synergy Project could never have accomplished all that it has. This section recognizes those individuals and, in particular, the role they played in "making it all happen":

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