Technology as a System of Systems
System Description

Abstract

This document is a System Description for Technology as a System of Systems. This System Description forms the core ontology for the Technology as a System of Systems Architecture Description Framework

Each technology domain can be considered a system of systems where the systems tend to be structured into:

- Networks of interacting systems
- Hierarchies of Systems

As each type of system is identified in the technology domain, the following benefits appear:

- Reuse of elements including design increases
- Families of related designs can be identified and their evolution managed.

PDF: System Description: Technology as a System of Systems (SoS), Version 0.2, 31-May-2021

Author and Version

Bruce McNaughton, Version 0.2, 31-May-2021

Contents

Revision History

V0.2 31-May-2021 Separation from Enterprise SD.

V0.1 18-Dec-2020 Update general technology models.

V0.0 27-February-2020 Initial Draft

System Description:Technology as a System of Systems

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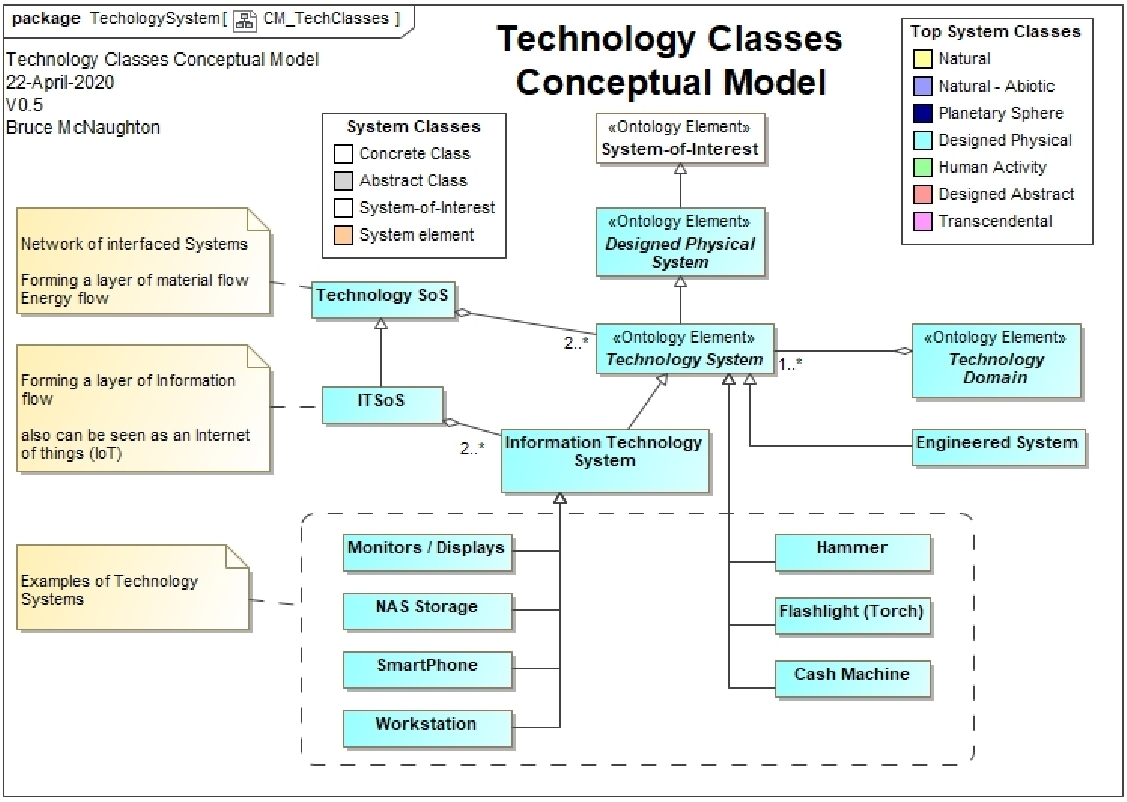
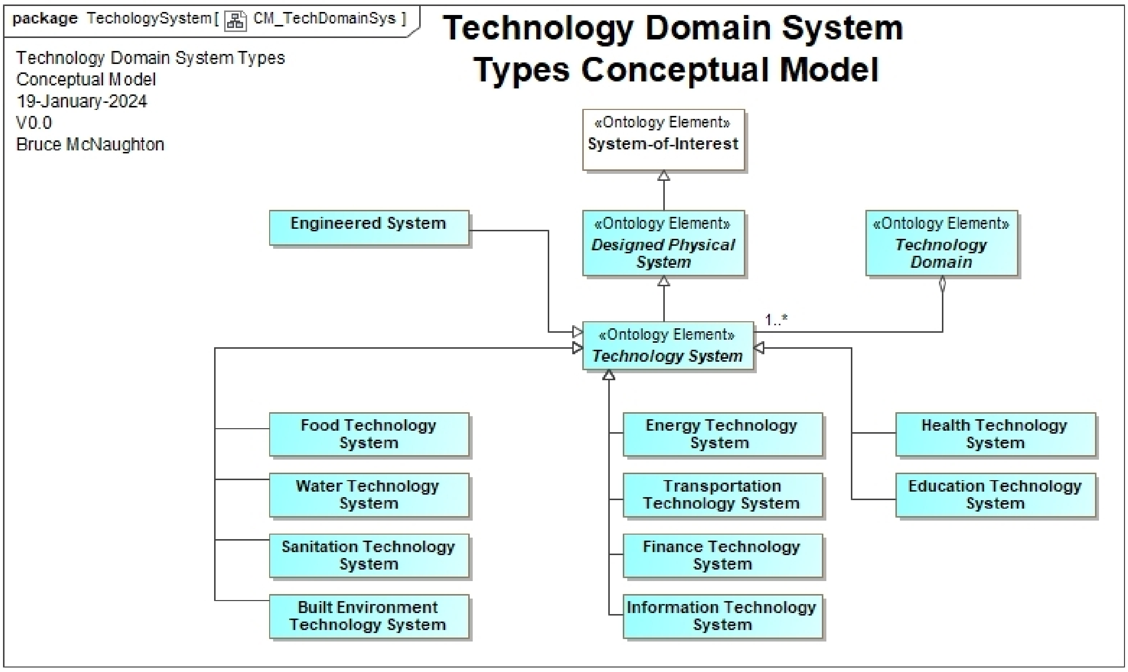
PDF: System Description: Technology as a System of Systems (SoS), Version 0.2, 31-May-2021

The system description incorporates the various example type technology systems:

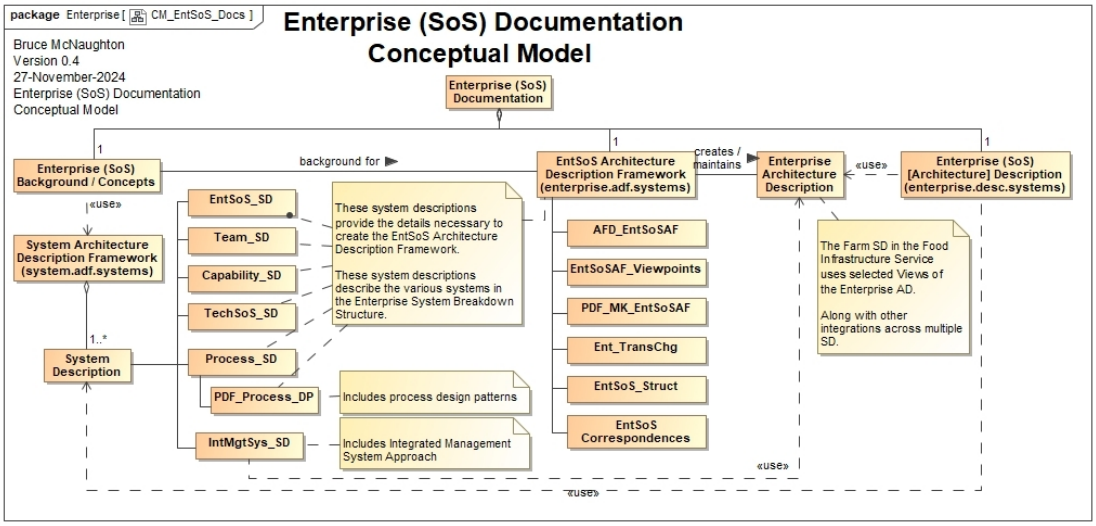


Technology Domain System Types are shown below (Initial List):



The technology system model that is being used in this document can create technology systems that are only physical technology. This model can also be used to create Technology Systems that are electtro-mechanical systems (such as an Information Technology System). The technology system model allows for any combination of technology and electrical combination. These systems could be classified as electromechanical systems.

The following diagram highlights the full set of information that supports the use of Enterprise (SoS) Documentation.



The following are links to the various documents that are available to read in PDF format.

[PDF: Enterprise (SoS) Background and Concepts, Version 0.3, 04-April-2025]

Link to [the System Description Architecture Description Framework]

System Description

[PDF: System Description: Enterprise as a System of Systems (SoS), Version 0.20, 25-November-2024]

[PDF: System Description: Team as a System, Version 0.11 15-December-2024]

[PDF: System Description: Capability as a System, Version 0.17 27-November-2024]

[PDF: System Description: Process (Human Activity), Version 0.5, 27-November-2024]

Link to [Process Design Patterns PDF]

[PDF: System Description: Integrated Management System, Version 0.18, 16-April-2025]

[PDF: System Description: Technology as a System of Systems (SoS), Version 0.2, 31-May-2021]

Link to [the Enterprise (SoS) Architecture Description Framework]

Link to EntSoSADF AVPD PDF

PDF: Structuring Formalism: System Description (SDSF), Version 0.4, 07-February-2023

Link to Current EntSoSADF Viewpoints PDF

Link to Current EntSoSADF Model Kinds PDF

Link to the EntSoSAF Correspondence Section

The Enterprise Transformation and Change PDF contains the Enterprise Transformation and Change Concepts. Version 0.5, 09-December-2022

Enterprise Architecture Description

Examples of Enterprise Architecture Descriptions are being prepared.

View: System Name and Class

Name: Technology System

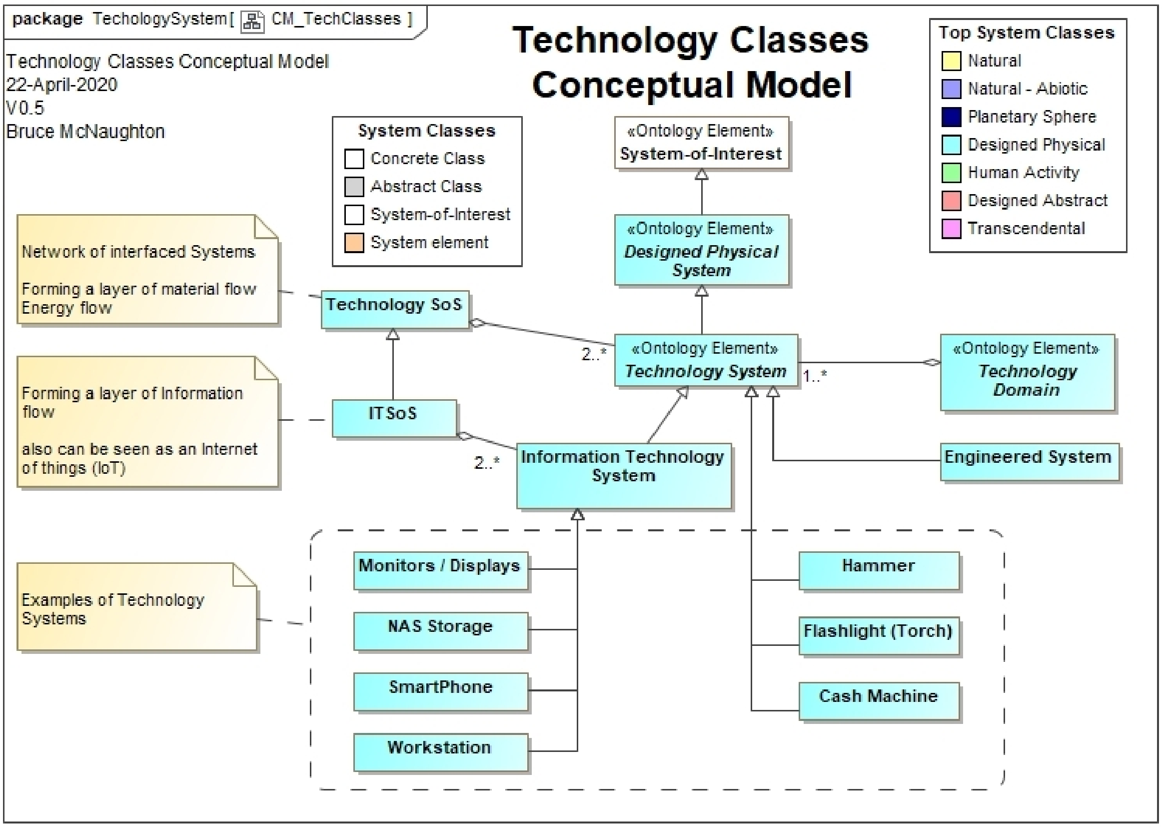
Based on: Designed Physical System.

> **Abstract System:** This system has been identified as an abstract system that cannot be implemented directly. The abstract system establishes a shared pattern of characteristics that any system can use to describe its unique characteristics when referenced in the 'based on' list above. These references are described using a generalization association in UML.

The technology system is a pattern of an IT enabled technology system (embedded systems) that may be used to describe electromechanical systems such as a technology system in a household Internet of Things (IoT). When the Information Technology System element is not present, the IoT interface will not be available.

The ability to connect a set of Technology Systems into a System of Systems (SoS) is also possible through the types of interfaces used to realize the network of systems.

The technology system can also be referred to as a 'designed physical system', an 'engineered system' or 'system-of-interest' in ISO 15288:2023.



View: System Purpose

The purpose of a abstract Technology System is to provide a pattern that can be used for any technology system that can be interconnected into an IoT. This abstract system can be used as a pattern for any technology (engineered system) developed within an Enterprise.

The Technology systems consist of two types of systems:

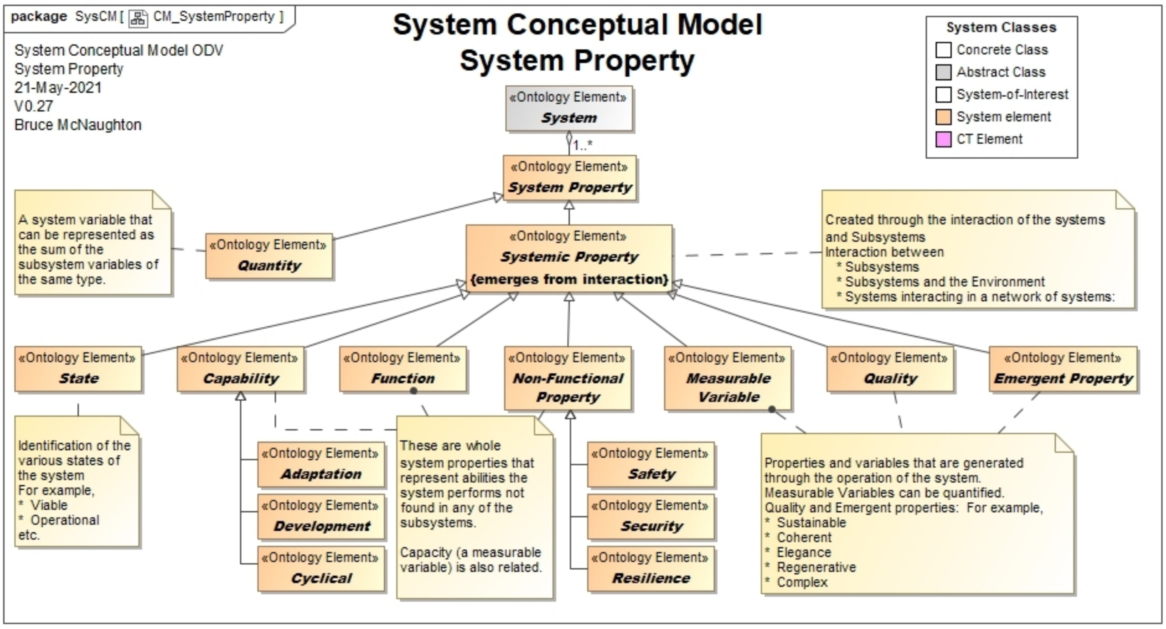
- One set of technology is common to all organizations
    - Information Technology (foundation element Information System). To be covered in an Information Technology Architecture Description Framework.TBD.
- One set of technology is unique to either production capabilities or product and service delivery.
    - Other technology: each system with their own Architecture Description Framework.
        - Transportation systems: e.g. Car, Aircraft
        - Food Processing
        - etc.

The technology systems are considered the 'white box' where the technology needs to be created or tailored in order to support the organization to achieve its purpose or objectives. The change or enabling system provides the means to create or tailor the technology. The enabling system to create the technology system is established using the Enterprise SoS ADF (or equivalent).

View: System Properties

System Properties Overview

The technology system properties generally fall into the following types shown in the diagram below:



Systemic Measurable Variables

The key measurable variables for technology are included for the specific type of technology system being described. Two examples are provided: Hammer and information technology system.

- Performance
- Throughput
- Capacity

Systemic Capabilities or Functions

The capabilities of the technology

- These are provided for a specific technology system

System States

An information system has the following states:

- Proposed
- Planned and Designed
- Developed
- Tested
- Operational
- Retired

(to be defined as part of the development of the CAFF for the Information Technology System of Systems (SoS)and in the Information Technology System of Systems (SoS) architecture description framework:

Systemic Quality Properties

These properties relate to qualitative properties of the system

- Non functional systemic properties
- Security, Safety, etc.
- MBTF
- Recycle approach

System Quantity Properties

These properties relate to aggregate totals for properties of the system (e.g. weight)

- Weight, Size, etc

View: System Stakeholders and Concerns

Operational Stakeholders

Manager

- is the technology fit for purpose in our team?
- do we have sufficient trained people to use and maintain the technology?
- do we understand the risks of using the technology?

People

- Do I understand the purpose and how to use any technology?
- Do I have the skills, knowledge and experience to carry out the work using the technology?
- Is the information system easy to use?
- Do I value the information system as a means to achieve my objectives?

Enabling System (programme, project, development, production, support)

Manager

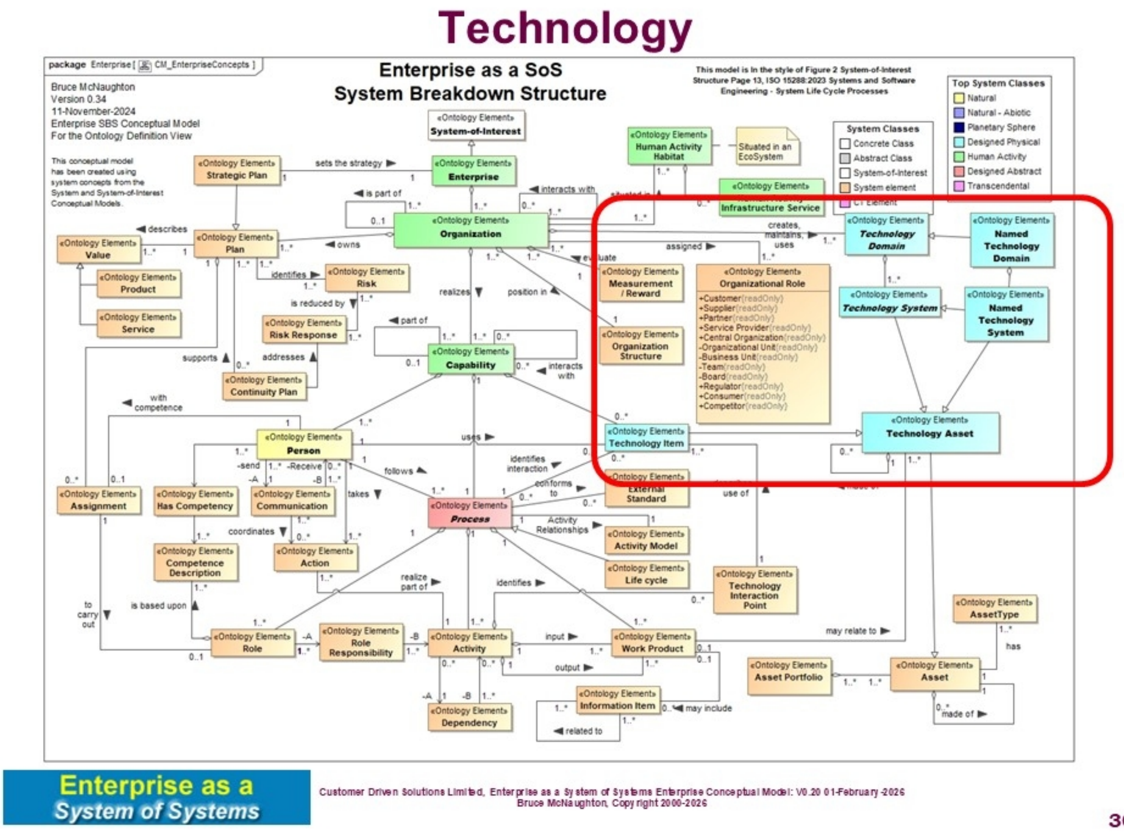
- Do we have the business case that justifies the development (costs / benefits)?
- Do we have a plan that is achievable?
- Have we understood all of the elements in the life cycle?

People.

- Do we understand the requirements for the technology?
- Do we have the skills, knowledge and experience to carryout the plan?
- Do we understand how the technology will be used?
- Do we understand the full life cycle elements necessary to produce the technology?

View: System Environment (Context)

Technology Systems within a technolog domain are managed through their life cycle within one or more enterprise systems.. This approach to Technology Systems provides a domain independent approach to architecting technology systems.



Technology Systems can be either COTS (Commercial off the shelf - typically black box) or developed within the organization (typically white box). The technology system in use becomes an asset of the organization.

The environment for the technology systems is both the full set of technology inside the enterprise and the specific technology used within an Organization. Other factors outside of the enterprise include:

- Rate of technology change
- Requirements and external standards that must be met
- Security and continuity requirements external to the enterprise.

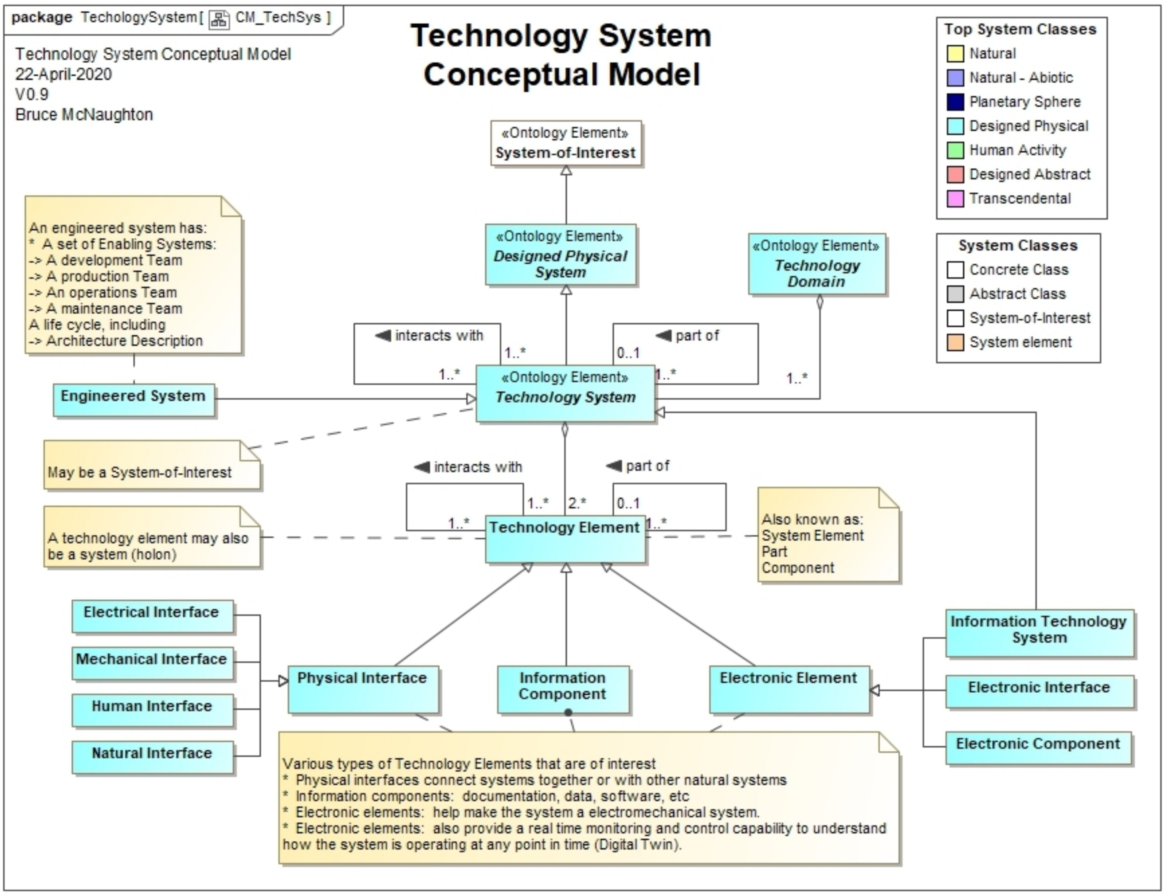
Interfaces and Flows

- What interfaces are involved with material flow?
- What interfaces are involved with energy flow?
- What interfaces are involved with information flow?
- What other interfaces are needed?

View: System Structure (Pattern of Organization)

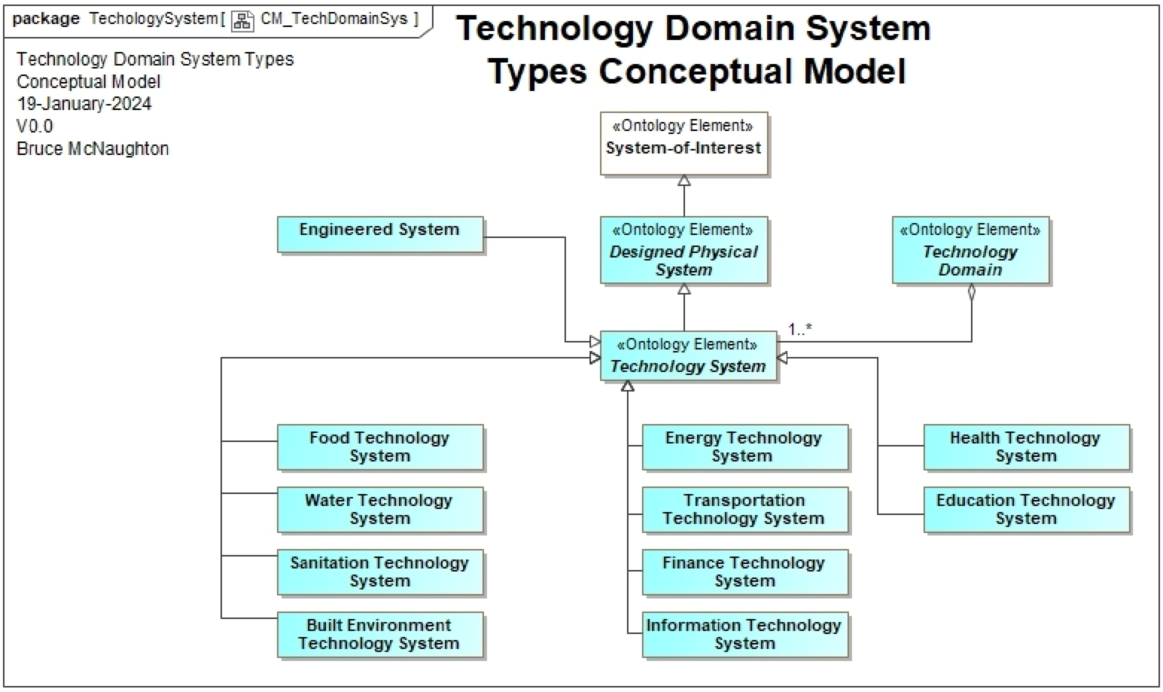
A technology system is the basic building block in the technology SoS.

System Element: Identification and Relationships

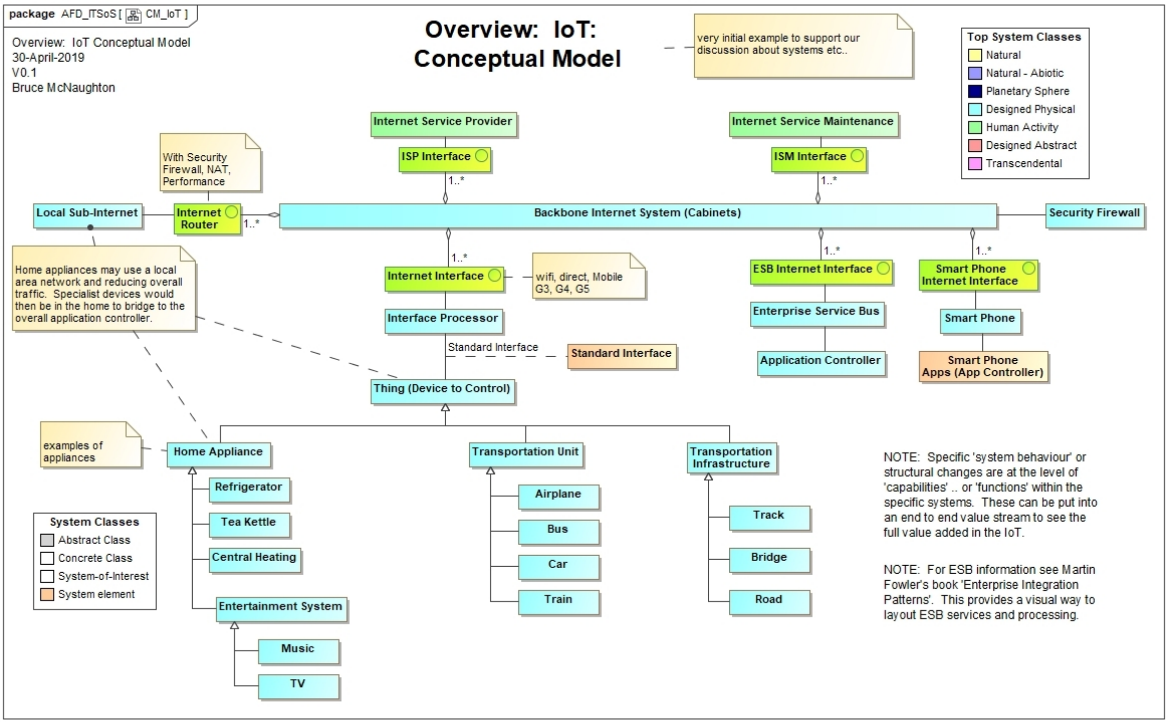


The model above can be used to describe a Digital Twin for a specific type of technology. The information system may include monitoring, and predictive methods to assess the state of the technology system.

The following Technology System types are shown below (initial list):



The following diagram shows the way the domain system types can be connected together in an IoT:

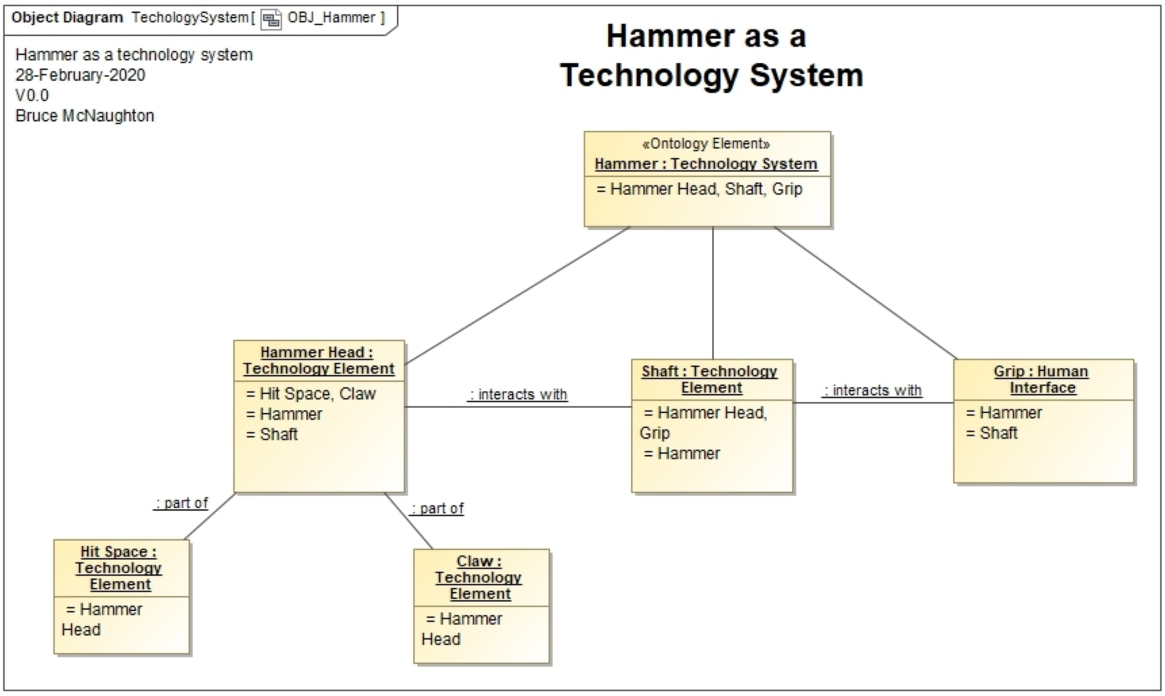


Technology Systems: Logical Model (Structure) Examples

This section highlights 3 Logical Model (Structure) Examples for Technology Systems. These would form part of the Structure section of a system description.

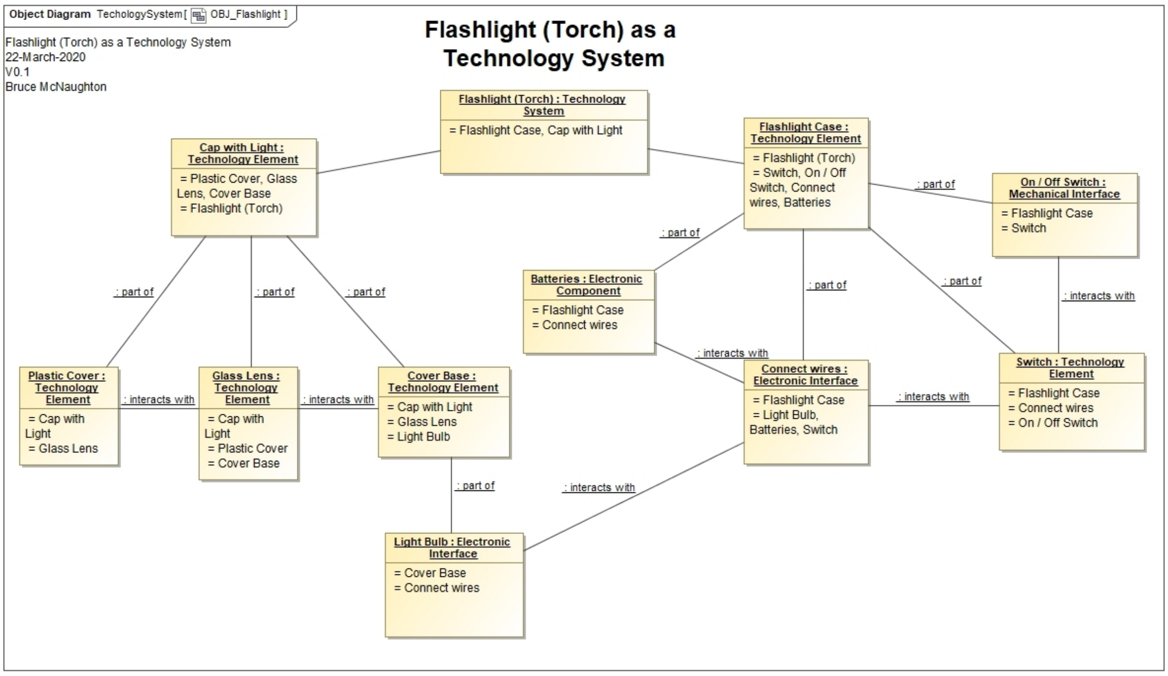
Hammer as a Technology System

The hammer is a simple technology system without any electronics. There are types of hammers that progressively include electronics and further information systems. These have not been included.



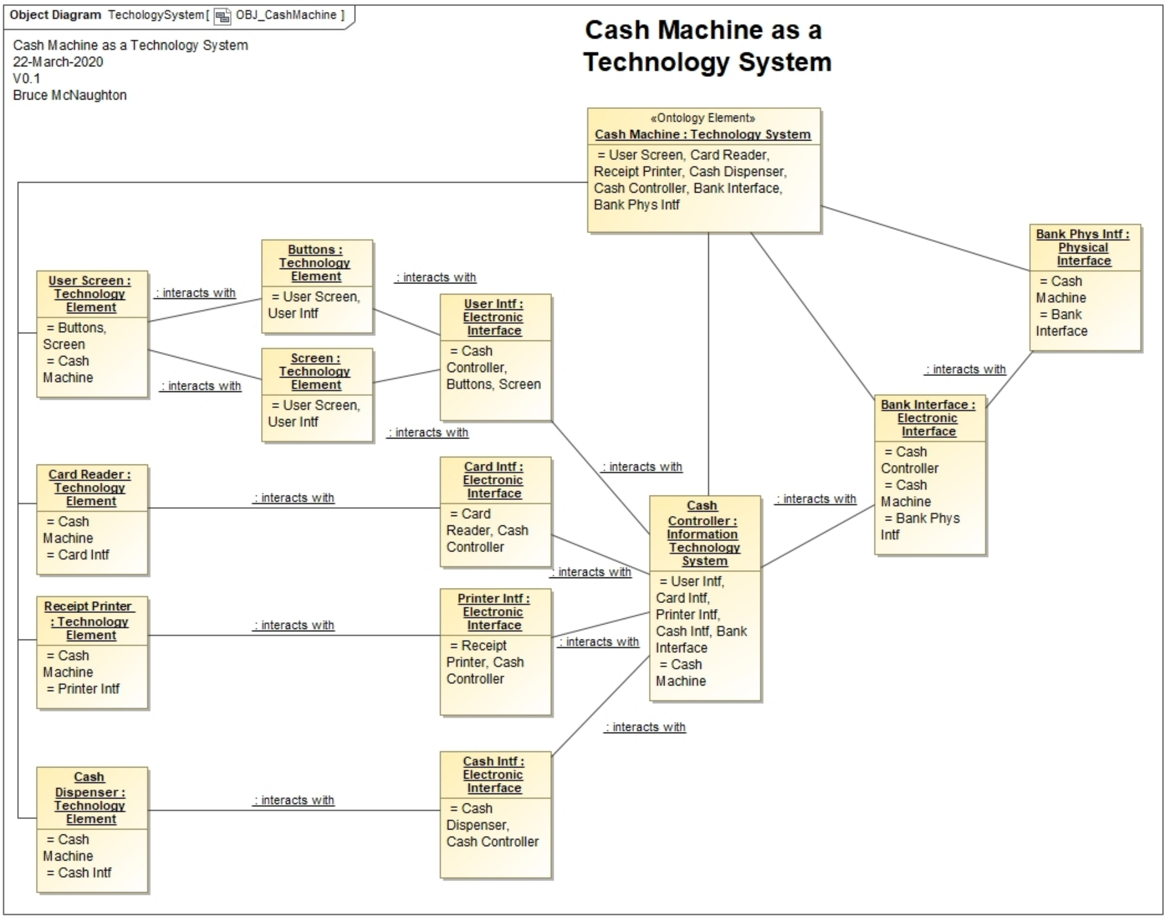
Flashlight (Torch) as a Technology System

The flashlight (Torch) has some electronics and mechanical enclosures and switches. Lighting as a type of system can get complex, for example, traffic lights.



Cash Machine as a Technology System.

The cash machine is a complex system of technology and electronic elements. The following example shows a top level. diagram of the elements. Some of the technology elements that are shwon can be considered technology systems in their own right.



System: Information Technology System of Systems (SoS)

System concepts are being applied to this system-of-interest within this System Description.

View: System Name and Class

Name: Information Technology System of Systems (SoS)

Based on: Technology System.

A Technology Item is a system element within the Capability. An Information Technology item supports the automation of a Capability by improving the effectiveness and the efficiency of the capability.

Technology refers to a type of engineered or designed system that an organization is responsible for. The organization will be responsible for the relevant parts of the technology life cycle.

Information Technology is the general sector of technology that applies to the information technology system.

NOTE: A specific Architecture Viewpoint Definition and associated conceptual models will be created to establish an Information Technology Archtiecture Framework. This has not started. The model above is a starting point for this work. Other existing architecture description frameworks will also be used in the creation of the AFD.

NOTE: Information Technology Systems may also have a role within other technology systems. These are typically called embedded information technology systems. These types of systems can also use the same information technology architecture description framework and similar development life cycles.

View: System Purpose

The purpose of an Information Technology System is to help people carry out their work and achieve their objectives within an organization. Productivity and efficiency improvements using technology are the key focus. The information technology system must be fit for purpose within the realization of an organizational capability.

View: System Properties

Systemic Measurable Variables

The key measurable variables for technology are:

Performance

- Computational speed
- Transfer speed
- Volume of calculations
- Time to change / improve

Usability

- Cost of training and learning
- Time saved by using the solution
- Reduction in errors

Systemic Capabilities or Functions

The capabilities of the Information technology

- Specific functions to automate activities within a process.
- Ability to collaborate and work in teams in near real time.
- Continued operation during faults or incidents.

System States

An information system has the following states:

- Proposed
- Planned and Designed
- Developed
- Tested
- Operational
- Retired

(to be defined as part of the development of the CAFF for the Information Technology System of Systems (SoS)and in the Information Technology System of Systems (SoS) architecture description framework:

Systemic Quality Properties

System Quantity Properties

View: System Stakeholders and Concerns

Manager

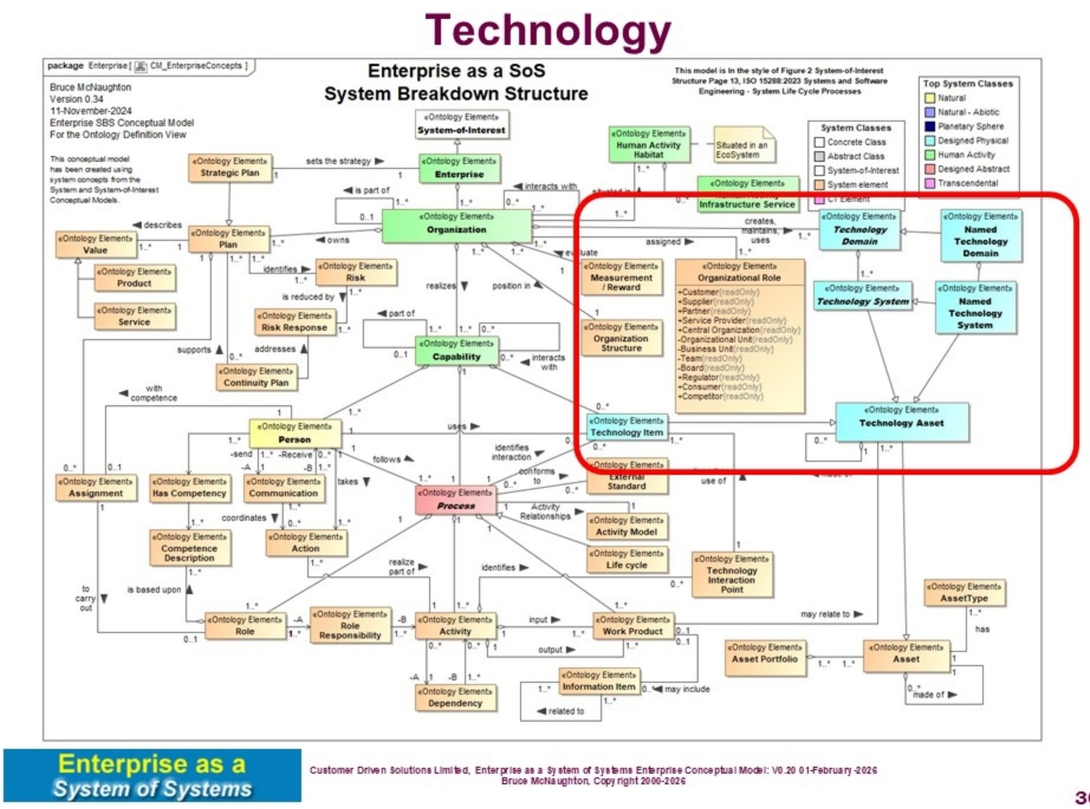
- Are the tools improving the productivity of the people in the team?
- Do I have sufficient quantities of tools to achieve our objectives / targets?

People

- Do I understand the purpose and how to use any technology?
- Do I have the skills, knowledge and experience to carry out the work using the tools?
- Is the information system easy to use?
- Do I value the information system as a means to achieve my objectives?

View: System Environment (Context)

Information Technology Systems form part of the Information Technology Systems needed for the enterprise. This information technology may be a subset of the entire set of technology used within an organization.



Information Technology Systems can be either COTS (Commercial off the shelf - typically black box) or developed within the organization (typically white box). The information technology system in use becomes an asset of the organization.

An information system fits within the full set of information systems used in a Organization. The total set of information systems is identified in the Information Technology Architecture Description. The network viewpoint highlights the number and types of information systems used in an organization.

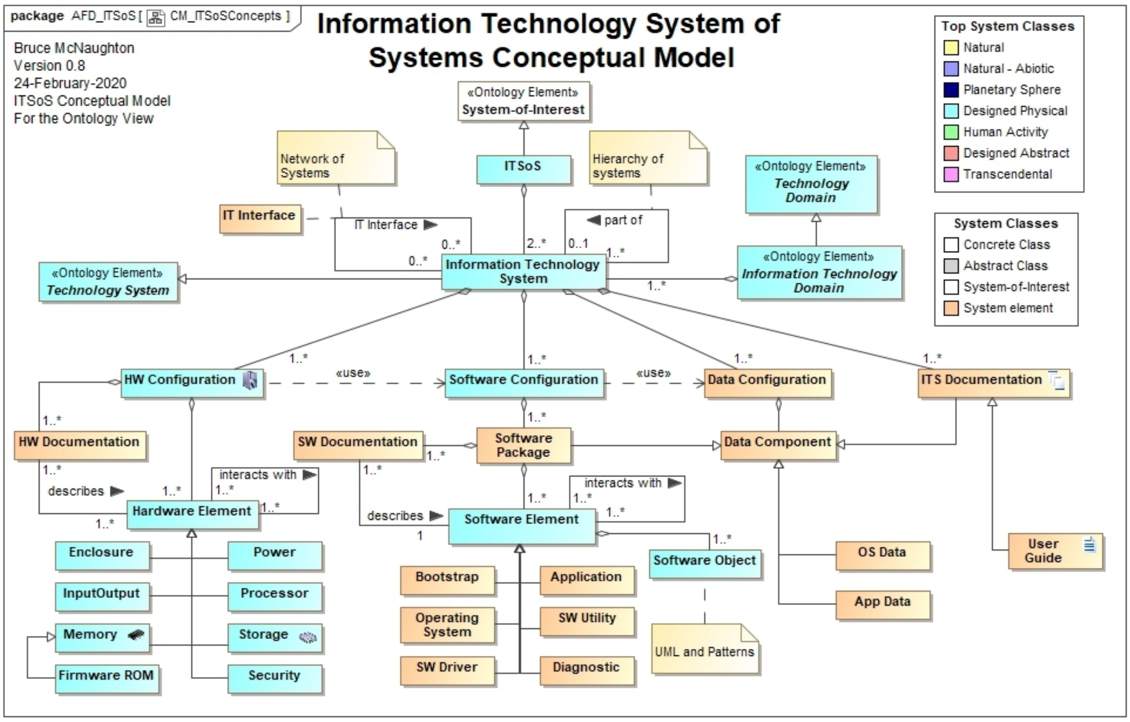
The environment for the information technology systems is both the full set of technology inside the enterprise and the specific technology used within a Organization. Other factors outside of the enterprise include:

- Rate of technology change
- Requirements and external standards that must be met
- Security and continuity requirements external to the enterprise.

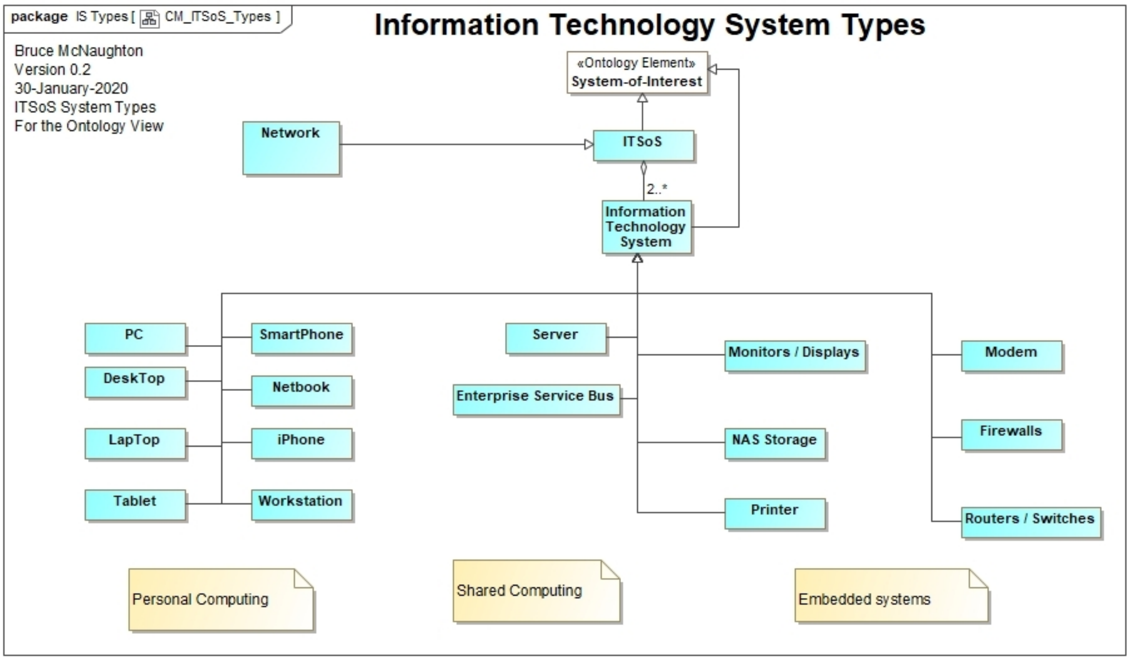
View: System Structure (Pattern of Organization)

An information system is the basic building block in the Information Technology System of Systems (SoS).

System Element: Identification

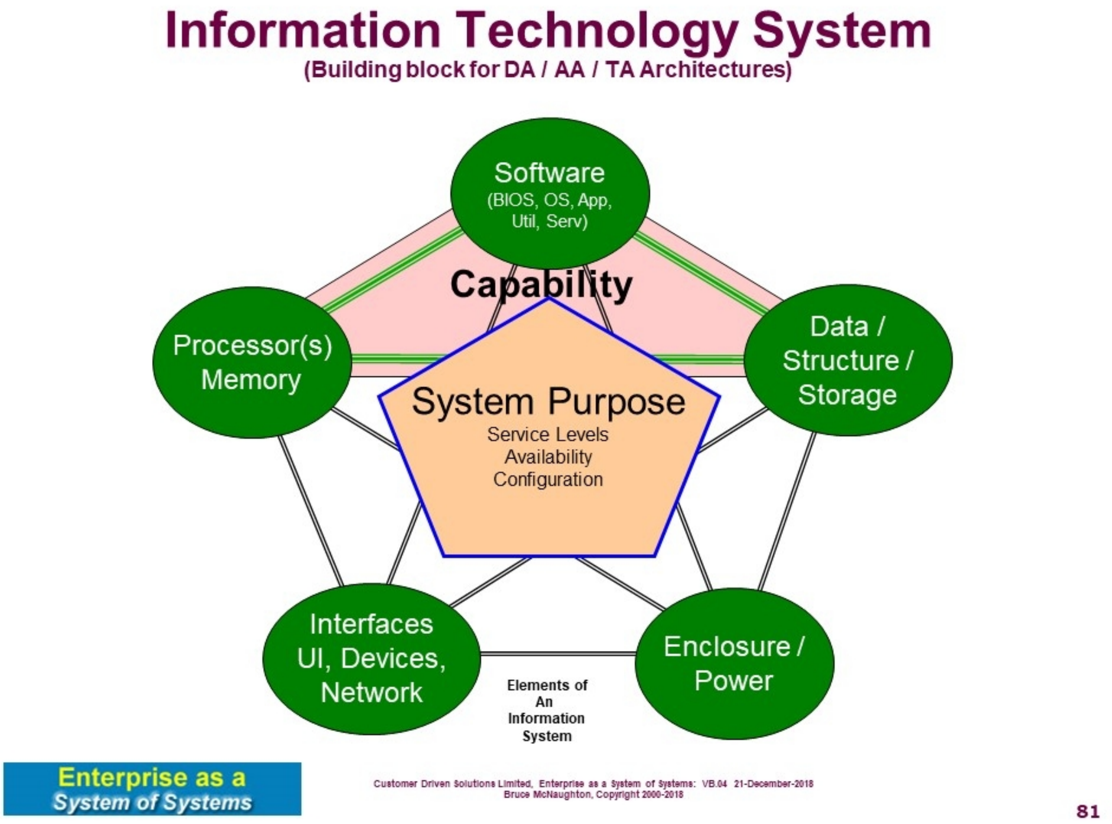


With the following Information Technology System types (initial list):



System Element: Identification and Relationships

The following is a picture of an information system. This is a fractal model similar to the team model and is a fundamental building block for the information Technology architecture description framework. This diagram shows the interactions of the various system elements within an Information Technology System.



- Purpose
- Enclosure / power
- Processor / Memory
- Software
- Data Storage
- Interfaces

The full collection of information systems used in an organization form the Information Technology System of Systems (SoS).

NOTE: The technology aspects of this website will be developed at a later time. See TOGAF for the domains of application, data, and infrastructure for an approach to this full Information Technology System of Systems (SoS).

View: System Behavior (Structural Changes)

Configuration / Scenario:

Describes any configuration / scenario attributes for a specific system-of-interest. This may not be appropriate for all system descriptions (e.g. patterns or abstract systems).

Cyclical (Repeating / Regular) Processes

The functions provided by the IT systems determine the fit of the system within the operational capabilities of the organization. These functions provide value to the people to carry out the process activities necessary for the capabilities.

Development Life Cycle Processes

Information systems may either be commodity products acquired through the procurement process or created specifically for the organisation using various new product / service development capabilities..

The architecture and design of an information system is handled through the Information Systems Innovation Life Cycle. Capabilities using this life cycle translate the requirements / needs as identified in the business process and the team management plans and create a tested and fit for purpose information system that supports the performance needs of the capability.

View: System Behavior (Structural Changes)

In order to establish the behavior of the system or system-of-interest, some understanding of the physical architecture of the system is necessary. This allows us to understand the behavior of the system at various points in time.

The Behavior (Structural Changes) section describes a specific instance (configuration of components) of a system structure that results in systems behaviour. The system behavior includes descriptions of the following as needed:

- a specific configuration or embodiment of a system structure (pattern of organization) (e.g. specific system elements or components, their relationships)
  - including any mathematical methods or characteristics of specific interaction types
- the triggers arising from a meaningful disturbance
- the process steps or sequence and any interaction in response to a specific trigger
- any models or data supporting the response along with any mathematical methods used.
- Any behavioral system or focused models (UML Diagrams, or Causal Loop Diagrams, etc.)

Configuration / Scenario: for the option or system-of-interest

Describes any configuration / scenario attributes for a specific system-of-interest. This may not be appropriate for all system descriptions (e.g. patterns or abstract systems).

Cyclical (Repeating / Regular) Processes

Normal Use

Maintance

Recivery from failure.

Development Life Cycle Processes

Adaptation

New Product Development (replacement of existiing)

References

Architecture / Design Core

Architecting Systems, Hillary Sillitto

Architecting Systems

Seven Sketches in Compositionality, Brendan Fong and David I. Spivak

Seven Sketches in Compositionality An Invitation to Applied Category Theory
Excellent Book with a unique way to introduce Category Theory based upon each chapter providing a firm foundation for the next topics.

UML 2 and the Unified Process, Jim Arlow and Ila Neustadt

UML 2 and the Unified Process: Practical Object-Oriented Analysis and Design (2nd Edition)
This book provides a view of UML throughout the system life cycle.

Competitive Engineering, Tom Gilb

Competitive Engineering: A Handbook For Systems Engineering, Requirements Engineering, and Software Engineering Using Planguage
Contains an approach to Impact Estimation

SysML for Systems Engineering, Jon Holt and Simon Perry

SysML for Systems Engineering
Includes a description of the Framework for Architecture Frameworks (FAF). This is the basis for the Compass Project CAFF.

Applying UML and Patterns, Craig Larman

Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development
Good examples for applying UML.

Diagnosing the System for Organisations, Stafford Beer

Diagnosing the System for Organizations
Easy way to learn the Viable System Model (VSM)

The Fractal Organization, Patrick Hoverstadt

The Fractal Organization: Creating Sustainable Organizations with the Viable System Model
VSM is used as a reference model

Object-Oriented Analysis and Design, James Martin and James J. Odell

Object-oriented Analysis and Design

Architecture / Design Standards

ISO 42010:2022 Software, Systems and Enterprise - Architecture Description

ISO 42010:2022 (Software, Systems and Enterprise - Architecture Description). ISO 42010:2022 replaces ISO 42010:2011 and IEEE 1472.
Main website for ISO 42010 is:
http://www.iso-architecture.org/42010/

Alternative website:
http://www.iso-architecture.org/
Conceptual Model contained in ISO 42010
http://www.iso-architecture.org/42010/cm/
Wikipedia: ISO 42010
Rich Hilliard
The architectural concepts from the Compass Project and this international standard have been integrated into the change and transformation approach.

ISO 42020:2019 Software, Systems and Enterprise - Architecture Processes

ISO 42020:2019 Software, Systems and Enterprise - Architecture Processes.

ISO 19439:2006 Enterprise integration -- Framework for enterprise modelling

- ISO 19439:2006 Enterprise integration -- Framework for enterprise modelling
- See also:
  - ISO 15704
  - ISO 19440
  - ISO 15531-1 Public Transport Communications Modelling

ISO 15704:2019 Enterprise modelling and architecture — Requirements for enterprise-referencing architectures and methodologies

ISO 15704:2019 Enterprise modelling and architecture — Requirements for enterprise-referencing architectures and methodologies
SEBoK Reference to ISO 15704:2000
See a

Various Standards for Terminology and Ontology Work.

Provides the Definitions and Methods for Terminology and Ontology Work.
There are various standards in this area:

- ISO 704:2022 Terminology Work Principles and Methods
- ISO 860:2007 Terminology Work Harmonization of Concepts and Terms
- ISO 1087:2019 Terminology work and terminology science — Vocabulary
  - Object
  - Concept
  - Characteristic
  - Concept System
  - Concept Model
- ISO 2382:2015 Information Technology Fundamental Terms
- ISO 10241-1:2011 Terminological Entries in Standards
- ISO 17115:2020 Industrial automation systems and integration - Parts Library
- ISO 13584-1:2001(en) Industrial automation systems and integration — Parts library
- ISO 24156-1:2014(en) Graphic notations for concept modelling in terminology work and its relationship with UML
- ISO 24765:2017 Systems and Software Engineering Vocabulary (will be replaced in next few months)
- ISO 24622-1:2015(en) Language resource management — Component Metadata Infrastructure (CMDI) — Part 1: The Component Metadata Model
- ISO 19505-1 OMG UML: Part 1 Infrastructure
- ISO 19505-2 OMG UML: Part 2 Superstructure
- ISO 24156-1:2014 UML for Terminology Work

Ontology Related Standards

- ISO 21838-1:2021 Top-level ontologies (TLO) — Part 1: Requirements
- ISO 21838-2:2021 Top-level ontologies (TLO) — Part 2: Basic Formal Ontology (BFO)
- Part 3
- Part 4
- Part 5
- Common Language

ISO Online Browsing Platform contains for all types of ISO information

- for specific terms; Select Terms and Definitions and then refine search by entering standard you are exploring.

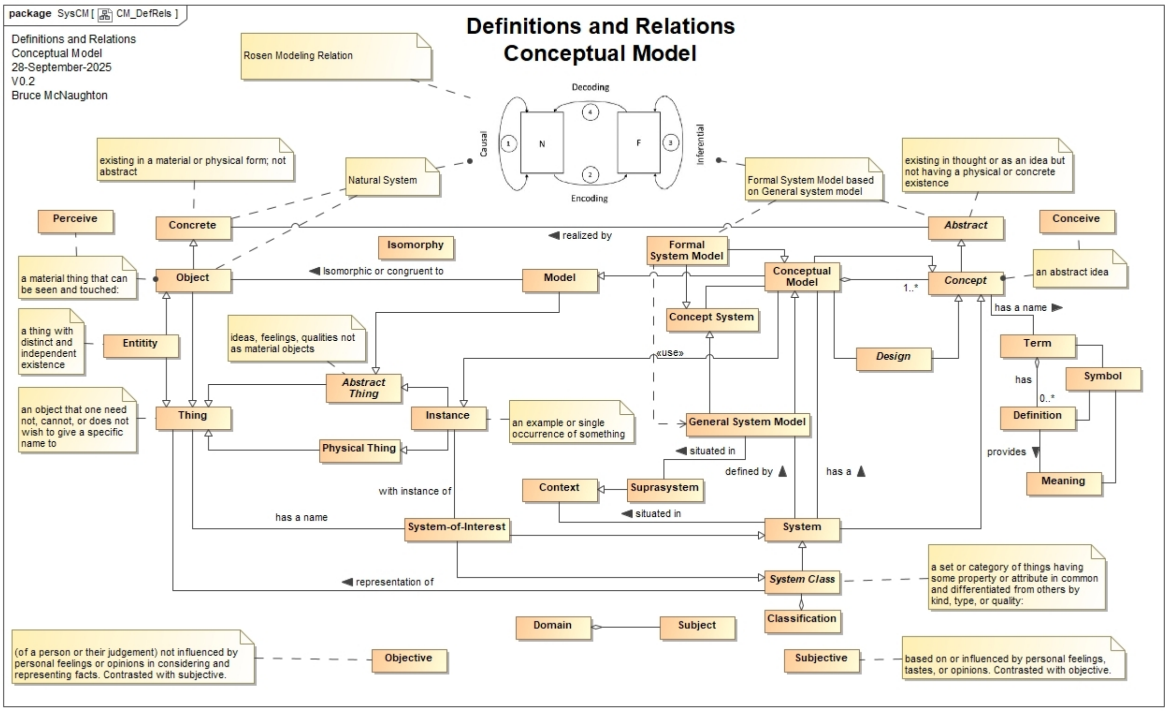
The following links relate to Management System Standards (MSS) and their Harmonization

- List of Harmonized Management System Standards (MSS)
- Annex SL provides guidance on Harmonization of MSS (is towards the end of this document link)
- Wikipedia: Annex SL

OMG Specifications

- OMG UML 2.5.1 Specification

Here is a working version of terminology aligned to Rosen's Modeling Relation that is being aligned to the above standards (work in progress).



Change Core

Managing Successful Programmes, MSP.

Managing Successful Programmes (MSP).

A programme management process used worldwide maintained by the UK Government.

Suitable for any types of programmes.

PRINCE2

Managing Successful Projects. PRINCE2

A project management process used worldwide maintained by the UK Government.

Suitable for any types of projects.

Management of Portfolios, MoP.

Management of portfolios

The Systems View of Life, Fritjof Capra and Pier Luigi Luisi

The Systems View of Life

This book is supported by the Capra Course which provides a 12 week course covering the four dimensions of life: Biological, Cognitive, Social, and Ecological.

A Capra Course Glossary is available in the Capra Course Alumni Network - A global Community of Practice related to the book.

See chapter 14 for information on Social Systems

Doughnut Economics, Kate Raworth

Doughnut Economics

Two models in the book are being used heavily in the development of the Human Activity Ecosystem models: The **Doughnut** and the **Embedded Economy**. The Doughnut is like a balanced scorecard for the planet and the Embedded Economy model is a good starting point to explore the systems that are creating the doughnut problems and the changes that are needed to bring the world into the doughnut safe and just place.

Kate Raworth and Herman Daly Video

Doughnut Economics pictures used with permission, Kate Raworth, 2017

Re-Creating the Corporation, Russell L. Ackoff

Re-Creating the Corporation: A Design of Organizations for the 21st Century

Definition of a System and 5 Conditions; Multi-Dimentional Organization Design; Interactive Planning; and more.

System of System Concepts

Thinking in Systems, Donella H. Meadows

Thinking in Systems: A Primer

Donella Meadows Project

System Description: Earth (Gaia) as a System of Systems

Please see the following Links for the System Description: Earth (Gaia) as a System of Systems.

- PDF: System Description: Earth (Gaia) as a System of Systems, Version 0.20, 07-January-2023 (working)
- Website: System Description: Earth (SoS)
- Presentation: Earth Systems Presentation, ISSS 11-July-2021, Current slides

System Description: Social System

Please see the following Links for the System Description: Social System.

- PDF:: System Description: Social System, Version 0.10, 03-November-2020
- Website:: natural.desc.systems: Social System
- ISSS Presentation: Living Social Systems

System Description: Person

Please see the following Links for the System Description: Person.

- PDF:: System Description: Person (Human Being), Version 2.4, 04-April-2023
- Website:: natural.desc.systems: Person as a System

System Description: System (Abstract)

Please see the following Links for the System Description: *System (Abstract)*.

- PDF: System Description: System (Abstract), Version 0.35, 13-February-2025 (working draft)
- Link to the System Description Architecture Description Framework
- Link to the System (Abstract) Architecture Viewpoint Definition
- PDF: Structuring Formalism: System Description (SDSF), Version 0.4, 07-February-2023
- Website: desc.systems: System

The System Description includes the following sections representing views of the system-of-interest:

- System Name and Class
- System Purpose
- System Properties
- System Stakeholders and their concerns
- System Environment (Context)
- System Structure (Pattern of Organization)
- System Behavior (Structural Changes)
- Correspondences
- Decisions and Rationale
- References

The following links help create a System Description

- Link to the System Description Template
- Link to the System Description Validation Template

The following are links to the COMPASS Project and the CAFF:

- Link to D21.5b Compass Architectural Framework Framework (Local): CAFF Viewpoint Definitions

Unified Modeling Language (UML)

UML is an Architecture Description Language used to create the Architecture Description Frameworks used in the various system areas.

UML is also a best practice method with extensive documentation.

- See UML
- See UML Conventions

As an Architecture Description Language, UML contains a number of diagrams described by Model Kinds. The following diagrams are used in the architectural area:

UML Structure Diagrams

- Class Diagram
- Object Diagram
- Package Diagram

UML Behavior Diagrams

- Activity Diagram
- Sequence Diagram
- State Machine Diagram
- Use Case Diagram

The diagrams have specific symbols / language elements that can be placed on a diagram. The instructions for creating each of these types of models is considered a Model Kind.

UML Modeling Conventions

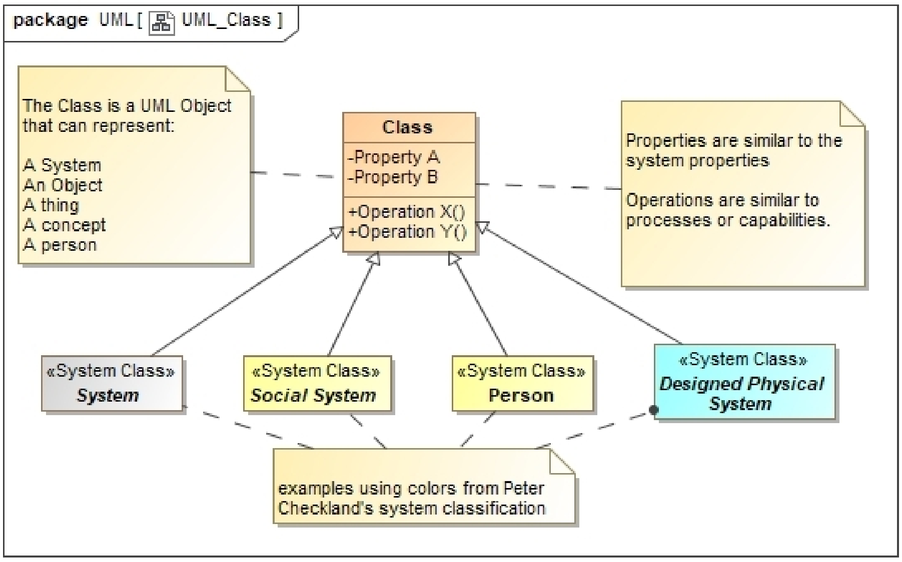
Unified Modeling Language (UML) provides a language for creating diagrams that have a consistent meaning.

This document contains the modeling conventions that apply to UML Class Diagrams as they apply to systems.

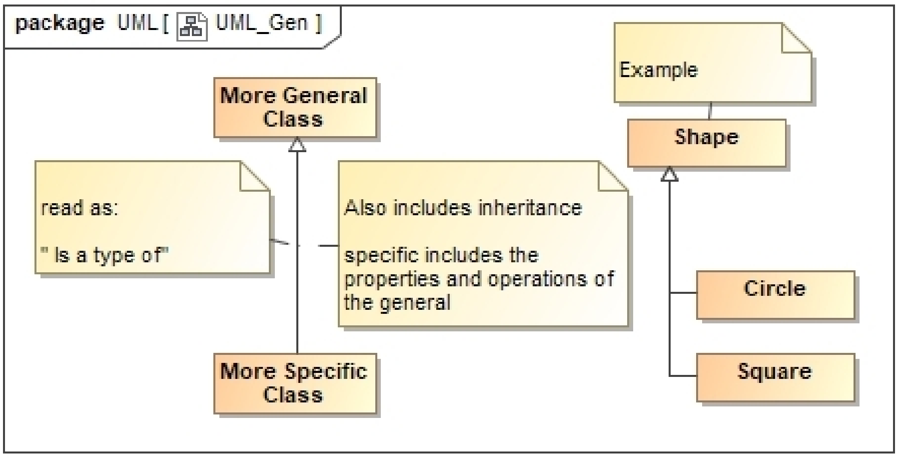
What are the modeling Conventions?

The following conventions from various modeling languages, such as the Unified Modeling Language (UML) or System Modeling Language (SysML) are also used in some of the system diagrams:

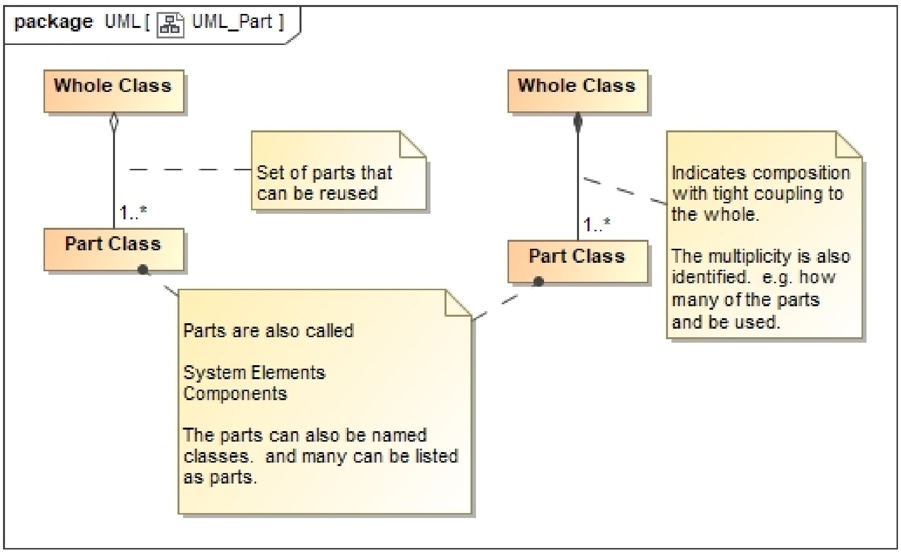
The UML Class symbol



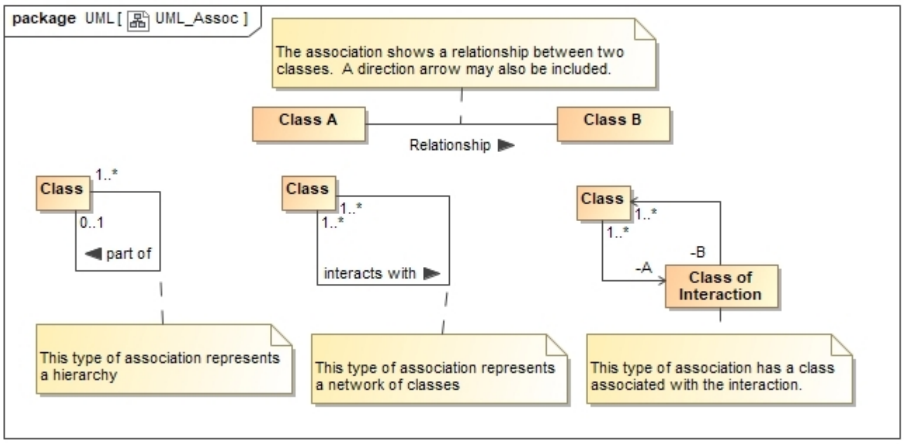
The UML Generalization Symbol



The UML Collection symbol



The UML Association symbol


package UML [UML_Assoc]
The association shows a relationship between two classes. A direction arrow may also be included.
Class A
Class B
Relationship
Class
1..*
0..1
part of
This type of association represents a hierarchy
Class
1..*
1..*
interacts with
This type of association represents a network of classes
Class
1..*
1..*
-A
-B
Class of Interaction
This type of association has a class associated with the interaction.