

LIFECYCLE MODELING LANGUAGE (LML) SPECIFICATION



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1 Specification Information

With the growth of the Internet and daily changes in Information Technology, systems have become more complex and change more rapidly than ever before. When coupled with ever tightening budgets and schedules it makes for a very challenging future. This is the challenge handed over to the modern Systems Engineer to resolve. Development of these systems requires:

- plans that are nimble and responsive to change,
- designs that are easy to understand by all stakeholders,
- architectures that are easy to modify,
- methodologies that are appropriate to the problem at hand,
- processes that support all stages of the system lifecycle.

Systems engineering approaches, methods and tools have evolved but have not kept pace with the rate of change of modern systems. Model Based Systems Engineering, SysML, DODAF, MODAF, and UAF are tremendous steps forward but do not address the entirety of the problem. Large portions of the development lifecycle are ignored by these approaches. A new approach to analyzing, planning, specifying, designing, building and maintaining modern systems is needed. The Lifecycle Modeling Language (LML) is that approach.

LML was designed with 6 major goals.

1. To be easy to understand,
2. To be easy to extend,
3. To support both functional and object oriented approaches within the same design,
4. To be a language that can be understood by most system stakeholders, not just Systems Engineers,
5. To support systems from cradle to grave,
6. To support both evolutionary and revolutionary changes to system plans and designs over the lifetime of a system.

Most of the systems engineering community recognizes MBSE's ability to evolve, reuse and execute models is a significant improvement over the classic "document-based" approach's static view of a system. These capabilities help to ensure a design of high quality. Good models can bridge the gap between written requirements and bending metal or writing code, the thing that is desired versus the thing that is delivered.

LML takes the principles of MBSE beyond the system development and production stages into the conceptual, utilization, support and retirement stages by providing a robust easy to understand ontology that allows one to model the complex interrelationships not only between system components but between those components and programmatic artifacts such as schedules and risk management plans using clear diagrams to express system information. LML was designed to integrate all lifecycle disciplines, including program management, systems and design engineering, as well as test, deployment and maintenance into a single framework. As a result, LML is a language that can be used throughout the lifecycle. LML uses common, everyday language to define its modeling elements such as entity, attribute, schedule, cost, relationship. It's primary modeling constructs are the box which represents whichever part of the system that is necessary, and the directed arrow which depicts a relationship between modeled elements such as "consists of," "derived from," "costs." This simplicity allows everyone from the least technical stakeholder to highly skilled end users to model and understand systems of arbitrary complexity. LML becomes the Rosetta Stone that allows easy communications between disparate disciplines across multiple industries.

1.1 Purpose of this Specification

The LML specification's purpose is to provide a reference for users of the language to understand its goals, concepts and structure and to provide vendors a reference for implementation of the language.

1.2 LML Steering Committee

The direction and evolution of this standard is overseen by the LML Steering Committee. It consists of expert systems engineers and program managers from industry and academia. Their charter is to ensure LML evolves in such a way that it continues to meet the needs of its user community. You may provide comments and suggestions on the LML website (www.lifecyclemodeling.org).

1.3 Documentation Conventions & Terminology

When referencing an entity, outside of a heading, the entity name is always in bold with the first letter capitalized, as in **Action**.

When referencing an attribute, outside of a heading, the attribute name is always in italics with the first letter lower case, as in *control*.

When clarification is needed to better identify an attribute, the entity name should be appended to the end of the attribute name as follows: “(**Entity Name**)”; where “**Entity Name**” would be the name of the entity. For example: *units*(**Characteristic**) and *units*(**Cost**), which clarifies the difference between the *units* attribute of the **Characteristic** entity and the *units* attribute of the **Cost** entity.

When referencing a relationship, outside of a heading, the relationship name is always in bold italics with first letter lower case, as in ***traced to***.

When referencing an attribute on a relationship, outside of a heading, the attribute name is always underlined with the first letter lower case, as in trigger.

When referencing the Lifecycle Modeling Language (LML) it is referenced via the full name, Lifecycle Modeling Language, or with the abbreviation, LML.

2 Overview of Lifecycle Modeling Language (LML)

The basis for the LML formulation is the classic entity, relationship, and attribute (ERA) meta-meta model. This formulation modifies the classical approach slightly by including attributes on relationships, to provide the adverb, as well as the noun (entity), relationship (verb), and attribute (adjective) language elements. Since LML was designed to translate to object languages, such as UML/SysML, these language elements correspond to classes (entity), relations (relationship), and properties (attribute).

Current Systems Engineering languages tend to add complexity to already complex problems, thus making it more difficult to communicate the underlying issues and develop effective solutions. LML is designed to be a simpler language, both in terms of its ontology and visual expressions. This feature makes it easy to understand by the entire set of lifecycle stakeholders. Such a simplified language may not include all the “bins” for information a particular domain wants, hence, LML is extensible allowing for discipline and domain specific extensions to support the needs of a specific project, organization or customer. The process for extension submission will be detailed on the lifecyclemodeling.org website.

For example, UML and SysML use the term Actor to define a part of the system that performs actions. The DoDAF Metamodel 2 uses the word Performer for the same purpose. LML uses the term, **Asset**, but also allows the user to extend the language by defining Actors or Performers. However, we recommend modelers use the *type* attribute for **Assets** instead, as a means to differentiate between these different names. New entities or child entities are recommended only when new attributes and/or relationships are needed. Thus modelers using LML will know what entity to put something in immediately and can adjust the *type* as needed. We saw this problem in the DoDAF where modelers were often confused by the difference between an operational node and a systems node. When you have two “bins” to put the same kind of information into confusion often results. Further examples of this comparison appear in Appendix A and B.

This specification of LML also defines common visualizations for information. For example, the *Risk* entity has a standard Risk Matrix as its basic diagram. Each entity has these kinds of common visualizations and they need to be as simple as possible to reduce the complexity of the language and make it more understandable by a broader set of stakeholders. Other visualizations are allowed and encouraged as they aid in expressing the information, which is the real goal of any language visualizations. These can and should be proposed as extensions to the language as well so that others practitioners can benefit from these visualizations.

Ontologies provide a set of defined terms and relationships between the terms to capture the information that describes the physical, functional, performance, and programmatic aspects of the system. By system,¹ we mean the entire set of processes, people and things which operate for the benefit of people. Common ways for describing such ontologies is entity, relationship, and attribute (ERA). ERA is often used to define database schemas. LML uses the ERA approach, but extends it by adding attributes to relationships. The extension reduces the number of relationships needed, just as attributes reduce the number of entities needed.

This section defines the ERAs for LML, thus providing the basic definitions of the data types used to collect information about the system. In addition, we describe how inheritance, extensions, limitations and instantiation can be used by tool developers to remain within the guidelines of this standard.

Entity, relationship and attribute have equivalent English language elements: noun, verb, and adjective. With the addition of attributes on the relationship, we also have the equivalent of the adverb. These equivalencies have been provided to aid in understanding the semantics of the language.

¹ INCOSE defines a system as a *combination of interacting elements organized to achieve one or more stated purposes*.

2.1 Entity (noun)

An entity is something can exist by itself and is uniquely identifiable. In LML, we have defined 12 parent entities (**Action**, **Artifact**, **Asset**, **Characteristic**, **Connection**, **Cost**, **Decision**, **Input/Output**, **Location**, **Risk**, **Statement** and **Time**). The rationale for this set is presented in Section 3. Several child entities have also been defined as they have specific utility in capturing the information needed by the system lifecycle stakeholders. The child entities are **Conduit** (child of **Connection**), **Logical** (child of **Connection**), **Measure** (child of **Characteristic**), **Orbital** (child of **Location**), **Physical** (child of **Location**), **Requirement** (child of **Statement**), **Resource** (child of **Asset**), and **Virtual** (child of **Location**). These child classes have the attributes and relationships of the parents plus additional attributes and relationships that make them unique. More on this “inheritance” of attributes and relationships is discussed in section 2.6. These twenty (20) entities shall be part of any LML-compliant language extension.

Every entity shall have a *name* or *number* or *description* attribute or combination of the three to identify it uniquely. The *name* is a word or small collection of words providing an overview of information about the entity. The *number* provides a numerical way to identify the entity. The *description* provides more detail about that entity.

In terms of the English language, an entity is like a noun.

2.2 Attribute (adjective)

An attribute is an inherent characteristic or quality of an entity. It further describes the entity, enhancing its uniqueness. Every attribute shall have a *name* to identify it uniquely within an entity. The *name* is a word or small collection of words providing an overview of information about the attribute. The attribute data type (see 2.5 below) specifies the data associated with the attribute.

Attributes names shall be name unique with in an entity, but may be used in other entities, such as the example provided earlier: *units*(**Characteristic**) and *units*(**Cost**) to avoid confusion within an entity specification.

In terms of the English language, an attribute is like an adjective.

2.3 Relationship (verb)

A relationship connects entities to each other. In LML, all relations shall be defined in both directions and shall have unique names with the same verb. For example, the standard parent child relationship (used by all LML entities) is **decomposed by** and its inverse is **decomposes**. Each relationship and its inverse shall have unique names. Relationship names also shall be unique across the whole schema. The relationships enable an English reading of the way entities connect. For example, when connecting an **Action** to a **Statement**, LML uses **traced from** as the relationship: an **Action** is **traced from** a **Statement**. The inverse relation of **traced from** is **traced to**, and thus would be read as: a **Statement** is **traced to** an **Action**. Figure 2-1 shows this and the Entity-Relationship Diagram (ERD) for this relationship.

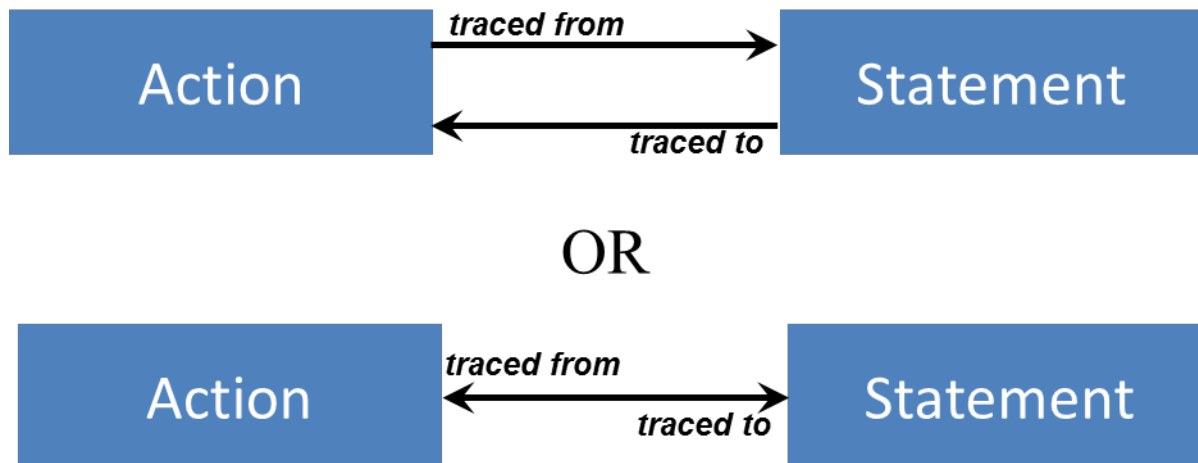


Figure 2-1. Entity Relationship Diagram for the Relationship Between an Action and a Statement.

For relationships within the same entity, such as decomposed by and decomposes can be visualized as an ERD as well (see Figure 2-2).



Figure 2-2. Entity Relationship Diagram for the Relationship Between an Action and Itself.

In terms of the English language, a relationship is like a verb.

2.4 Attributes on Relationships (adverb)

The classic ERA modeling does not include attributes on relationships. However, for LML this addition is very useful.

Figure 2-3 shows an example of how the attribute on a relationship is depicted in an extended version of the ERD. The attribute on a relationship is shown with a dashed line to the relationship. The attribute on a relationship shall have a unique name for that relationship, but can be used in other relationships, if necessary to enhance communications.

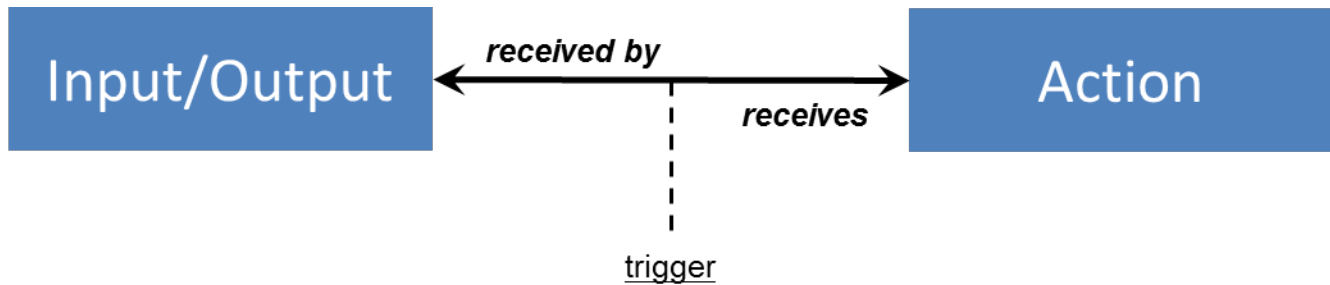


Figure 2-3. Extended Entity Relationship Diagram for the Attribute on the Relationship Between an Action and an Input/Output.

In terms of the English language, an attribute on a relationship is like an adverb.

2.5 Attribute Data Types

For a complete specification, it is essential to define the data types appropriate for the attributes, as they can vary significantly and without this specification interoperability with other schemas (i.e., translations) would be very difficult. The following sub-sections present the current acceptable set of attribute data types for LML. Extensions (see Section 2.7) may also extend this list of data types as well.

2.5.1 Text

A Text data type represents: a single character, single word, or multiple words.

2.5.2 Number

A Number data type represents any individual real number.

2.5.3 Boolean

A Boolean data type represents the two possible logical values “true” and “false”.

2.5.4 Percent

A Percent data type represents a special case of Number where the value is restricted to values between zero and one hundred, inclusive.

2.5.5 DateTime

A DateTime data type represents a specific method of storing a given date and time value. Commonly stored as “YYYY-MM-dd hh:mm:ss”. Where “YYYY” is the four digit year, “MM” is the two digit month, “dd” is the two digit day, “hh” is the two digit hour (in twenty-four hours), “mm” is the two digit minute, and “ss” is the two digit second.

2.5.6 URI

An URI data type represents a special case of Text where the value must be a Uniform Resource Identifier. Examples of URI: “C:/Program Files”, “http://www.google.com”, and “test@test.com”.

2.5.7 Enumeration

An Enumeration data type represents a set of defined choices, where the selection of only one choice is permitted. An enumeration must contain at minimum two choices. All choices within the set must be of the same data type (having a set containing Text data type and Number data type is not permitted). Also, within a set a repeated choice is not permitted (A set cannot have repeated “Apple” as in: “Apple”, “Orange”, “Apple”, and “Plum”).

2.5.8 GeoPoint

A GeoPoint data type represents a longitude and latitude pair on the surface of a body.

2.6 Inheritance

With LML it is possible to create child entities. The child entity inherits all the attributes and relationships from the parent entity with the EXCEPTION of the attribute *type*; this attribute is overridden by the child entity.

An example of a child entity is **Resource** with parent entity **Asset**.

A child entity will also inherit relationships from the parent. Additional relationships may also be defined for the child.

2.7 Extensions

Extensions for domain-specific needs are allowed and encouraged when necessary. However, it is strongly recommended however to avoid simply aliasing the current ontology, but instead to identify aliases as another “*type*” of the entity, which is a common attribute for every entity. Tool developers may want to display the entity *type*, rather than the entity *name* to enhance the communication with these other languages.

The schema user can also apply **Characteristic** entity in many cases to provide “attributes” of an **Asset** or **Action**, thus making many other extensions unnecessary. It is recommended to explore this option first, before creating an extension.

All extension must be submitted to the LML Steering Committee for adjudication before they will be recognized as official extensions to LML.

2.8 Instantiation

Actual instantiation of the LML specification will be up to tool vendors. If they find portions of the specification difficult to implement, they can apply to the LML Steering Committee for guidance.

3 LML Ontology

Systems engineers, enterprise architects and program managers have overlapping needs for information and LML provides a basic but comprehensive set of design elements that satisfy them all. For example, the systems engineer is concerned with optimizing cost, schedule and performance. Performance includes form, fit, and function. Enterprise architects often use the “5WH” model (What, Why, When, Where, Who, and How) to capture their information. The Program Manager is primarily concerned with cost, schedule, tasks, resources, and risks. Table 3-1 shows these various information needs and how LML satisfies them. Each of these entities has unique and common attributes and relationships.

Table 3-1. Comparison Between LML and the Information Needs of Key System Lifecycle Stakeholders

Systems Engineering	Architecture	Program Management	Lifecycle Modeling Language
Cost	(How Much)	Cost	Cost
Schedule	When	Schedule	Time/Action
Performance			
<i>Form</i>	Who	Organization	Asset
	What	Resource	Resource
	Where	Location	Location
	Why	Goal, Objective & Decision	Decision & Statement/Requirement
<i>Function</i>	How	Task	Action
<i>Metric (Fit)</i>		Metric	Characteristic/Measure
<i>Interface</i>			Connection (Conduit) & Input/Output
Risk		Risk	Risk
		Artifact	Artifact

This section provides an overview of LML and then subsequently delves into the detailed attributes, relationships, and attributes on relationships for each entity. This information is fundamental for tool developers planning to instantiate LML.

3.1 LML Entities

Table 3-2 summarizes the LML entities, their parent entity, description and examples (where appropriate) of how they might be used. Note that these examples can be part of the *type* attributes used as aliases for the entity itself.

Table 3-2. Summary of the LML Entities

Entity Name	Parent Entity	Description	Examples
Action	None	An Action entity specifies the mechanism by which inputs are transformed into outputs.	Activity, Capability, Event, Function, Process, Task
Artifact	None	An Artifact entity specifies a document or other source of information that is referenced by or generated in the knowledgebase.	Document, E-mail, Procedure, Specification
Asset	None	An Asset entity specifies an object, person, or organization that performs Actions, such as a system, subsystem, component, or element.	Component, Entity, Service, Sub-system, System
Characteristic	None	A Characteristic entity specifies properties of an entity.	Attribute, Category, Power, Role, Size, Weight
Conduit	Connection	A Conduit entity specifies the means for physically transporting Input/Output entities between Asset entities. It has limitations (attributes) of capability and latency.	Data Bus, Interface, Pipe
Connection	None	A Connection entity specifies the means for relating Asset instances to each other.	Abstract entity
Cost	None	A Cost entity specifies the outlay or expenditure (as of effort or sacrifice) made to achieve an objective associated with another entity.	Earned Value, Work Breakdown Structure, Actual Cost, Planned Cost
Decision	None	A Decision entity specifies a challenge and its resolution.	Major Decision, Challenge, Issue, Problem
Input/Output	None	An Input/Output entity specifies the information, data, or object input to, trigger, or output from an Action .	Item, Trigger, Information, Data, Energy
Location	None	A Location entity specifies where an entity resides.	Abstract entity
Logical	Connection	A Logical entity represents the abstraction of the relationship between two entities (e.g., Asset entities with the type "Entity")	Has, "is a", "relates to"
Measure	Characteristic	A Measure entity specifies properties of measurements and measuring methodologies, including metrics.	Key Performance Parameter (KPP), Measure of Effectiveness (MOE), Measure of Performance (MOP), Metric

Entity Name	Parent Entity	Description	Examples
Orbital	Location	An Orbital entity specifies a location along an orbit around a celestial body.	Orbit
Physical	Location	A Physical entity specifies a location on, above, or below the surface.	Map Coordinates
Requirement	Statement	A Requirement entity identifies a capability, characteristic, or quality factor of a system that must exist for the system to have value and utility to the user.	Functional Requirement, Performance Requirement, Safety Requirement
Resource	Asset	A Resource entity specifies a consumable or producible Asset .	Fuel, Bullets, Missiles, People
Risk	None	A Risk entity specifies the combined probability and consequence in achieving objectives.	Cost Risk, Schedule Risk, Technical Risk
Statement	None	A Statement entity specifies text referenced by the knowledgebase and usually contained in an Artifact .	Need, Goal, Objective, Assumption
Time	None	A Time entity specifies a point or period when something occurs or during which an action, asset, process, or condition exists or continues.	Milestone, Phase
Virtual	Location	A Virtual entity specifies a location within a digital network.	URL

3.2 LML Relationships

The relationships between the entities are provided in the Table 3-3. Note that the same verb is used for the inverse relationships.

* - Implies the inverse relation is present, just not shown.

Note: This matrix does not include the extensions for SysML, which can be found in Appendix A.

Table 3-3. Summary
Table of LML
Relationships

	Action	Artifact	Asset (Resource)	Characteristic (Measure)	Connection (Conduit, Logical)	Cost	Decision	Input/Output	Location (Orbital, Physical, Virtual)	Risk	Statement (Requirement)	Time
Action	decomposed by* related to*	references	(consumes) performed by (produces) (seizes)	specified by	-	incurs	enables results in	generates receives	located at	causes mitigates resolves	(satisfies) traced from (verifies)	occurs
Artifact	referenced by	decomposed by* related to*	referenced by	referenced by specified by	defines protocol for referenced by	incurs referenced by	enables referenced by results in	referenced by	located at	causes mitigates referenced by resolves	referenced by (satisfies) source of traced from (verifies)	occurs
Asset (Resource)	(consumed by) performs (produced by) (seized by)	references	decomposed by* orbited by* related to*	specified by	connected by	incurs	enables made responds to results in	-	located at	causes mitigates resolves	(satisfies) traced from (verifies)	occurs
Characteristic (Measure)	specifies	references specifies	specifies	decomposed by* related to* specified by*	specifies	incurs specifies	enables results in specifies	specifies	located at specifies	causes mitigates resolves specifies	(satisfies) spacifies traced from (verifies)	occurs specifies
Connection (Conduit, Logical)	-	defined protocol by references	connects to	specified by	decomposed by* joined by* related to*	incurs	enables results in	transfers	located at	causes mitigates resolves	(satisfies) traced from (verifies)	occurs
Cost	incurred by	incurred by references	incurred by	incurred by specified by	incurred by	decomposed by* related to*	enables incurred by results in	incurred by	located at	causes incurred by mitigates resolves	incurred by (satisfies) traced from (verifies)	occurs
Decision	enabled by result of	enabled by references result of	enabled by made by responded by result of	enabled by result of specified by	enabled by result of	enabled by incurs result of	decomposed by* related to*	enabled by result of	located at	causes enabled by mitigated by result of resolves	alternative enabled by traced from result of	date resolved by decision due occurs
Input/Output	generated by received by	references	-	specified by	transferred by	incurs	enables results in	decomposed by* related to*	located at	causes mitigates resolves	(satisfies) traced from (verifies)	occurs
Location (Orbital, Physical, Logical)	locates	locates	locates	locates specified by	locates	locates	locates	locates	decomposed by* related to*	locates mitigates	locates (satisfies) traced from (verifies)	occurs
Risk	caused by mitigated by resolved by	caused by mitigated by references resolved by	caused by mitigated by resolved by	caused by mitigated by resolved by specified by	caused by mitigated by resolved by	caused by incurs mitigated by resolved by	caused by enables mitigated by results in resolved by	caused by mitigated by resolved by	located at mitigated by	caused by* decomposed by* related to* resolved by*	caused by mitigated by resolved by	occurs mitigated by
Statement (Requirement)	(satisfied by) traced to (verified by)	references (satisfied by) sourced by traced to (verified by)	(satisfied by) traced to (verified by)	(satisfied by) specified by traced to (verified by)	(satisfied by) traced to (verified by)	incurs (satisfied by) traced to (verified by)	alternative of enables traced to results in	(satisfied by) traced to (verified by)	located at (satisfied by) traced to (verified by)	causes mitigates resolves	decomposed by* traced to* related to*	occurs (satisfied by) (verified by)
Time	occurred by	occurred by	occurred by	occurred by specified by	occurred by	occurred by	date resolves decided by occurred by	occurred by	occurred by	occurred by mitigates	occurred by (satisfies) (verifies)	decomposed by* related to*

3.3 Traceability

Since LML was designed to support traceability of requirements to their implementation mechanisms (Asset class entities), the primary path for traceability is in Figure 3-1. This diagram does not reflect all the relationships shown in Table 3-3.

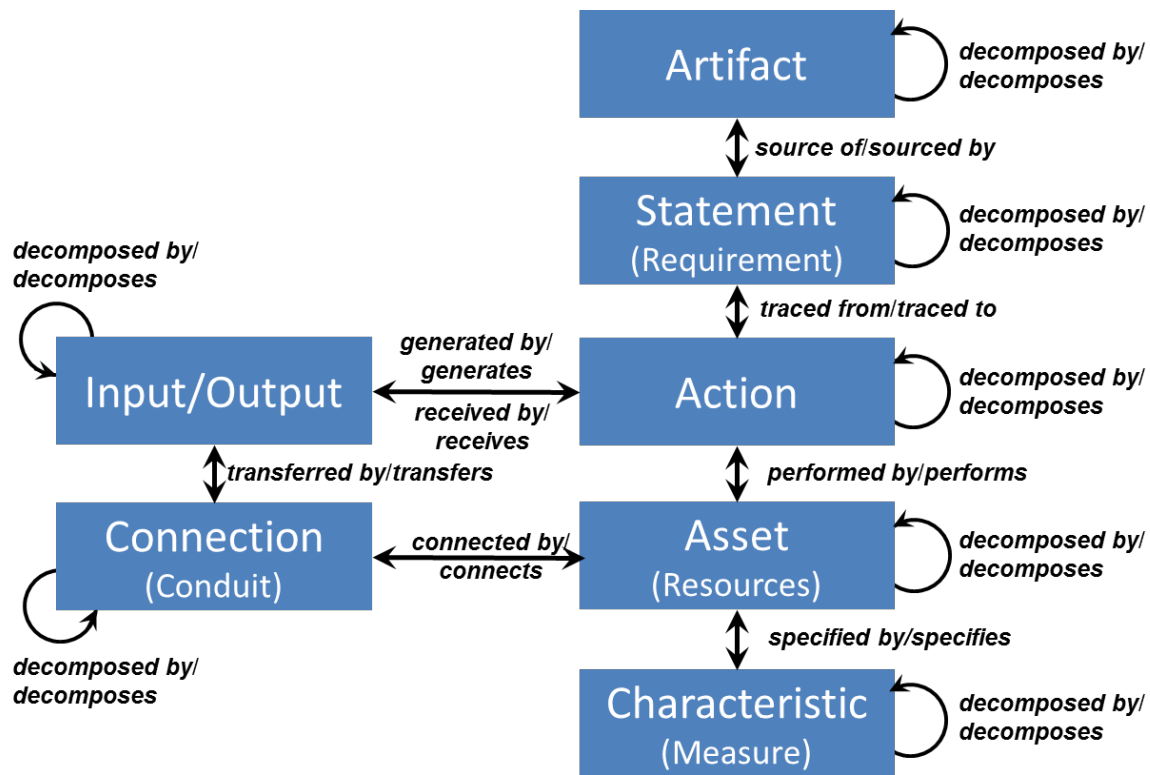


Figure 3-1. Principal Entities and Relationships for Design LML Traceability

3.4 Entity Specifications

The following tables and subsections provide the detailed entity, relationship and attribute specifications for the LML ontology. These specifications shall be used by language users to provide the basis for all LML-related extensions. **Inverse** provides the name of the relationship from the perspective of the target entity. **Target entity(ies)** provides the name of the entity(ies) on the other side of the relationship.

These attributes are common to all entities.

Attribute	Data Type	Description
<i>name</i>	Text	<i>name</i> designates the particular instance of an entity called element.
<i>number</i>	Text	<i>number</i> provides the element's place in a hierarchy.
<i>description</i>	Text	<i>description</i> captures the text needed to describe this element.

3.4.1 Action

Entity	Parent Entity	Child Entities	Description
Action	None	None	An Action entity generates effects and may have pre-conditions before it can be executed. This Action can include transforming inputs into outputs. Examples: Process, Discover, Calculate.

Attribute	Data Type	Description
<i>duration</i>	Number	<i>duration</i> represents the period of time this Action occurs.
<i>percent complete</i>	Percent	<i>percent complete</i> represents the percentage this Action is complete.
<i>start</i>	DateTime	<i>start</i> represents the time when this Action begins.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Action these can include: Activity, Capability, Event, Function, Mission, Operational Activity, Program, Service Orchestration, Simulation Workflow, Subprocess, System Function, Task, Training, Use Case, Work Process, Workflow

Relationship	Inverse	Target Entity	Description
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
consumes	consumed by	Resource	consumes identifies the Resource that this Action uses. After this Action is completed the amount consumed is not returned to the Resource .
	Attribute	Data Type	Description
	amount	Number	amount represents how much of the resource is consumed by the Action . Units are relative to the units selected for the Resource .
decomposed by	decomposes	Action	decomposed by identifies the children of this entity.
decomposes	decomposed by	Action	decomposes identifies the parent of this entity.
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
generates	generated by	Input/Output	generates identifies the Input/Output that this Action transforms.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
located at	locates	Location	located at identifies the Location where this entity exists.

Relationship	Inverse	Target Entity	Description
mitigates	<i>mitigated by</i>	Risk	mitigates identifies the Risk that this entity plan alleviates.
occurs	<i>occurred by</i>	Time	occurs identifies the Time (or timespan) this entity happens.
performed by	<i>performs</i>	Asset	performed by identifies the Asset that executes this Action .
produces	<i>produced by</i>	Resource	produces identifies the Resource that is created by this Action . Resources are produced when the execution of the Action completes.
	Attribute	Data Type	Description
	<u>amount</u>	Number	<u>amount</u> represents how much of the Resource is produced by the Action . Units are relative to the units selected for the Resource .
receives	<i>received by</i>	Input/Output	receives identifies the Input/Output that is taken in by this Action .
	Attribute	Data Type	Description
	<u>trigger</u>	Boolean	<u>trigger</u> represents this relation as an enabling requirement for the Action . An Action begins execution when it has received control enablement, all of its <u>triggers</u> have arrived, and its necessary resources are available.
references	<i>referenced by</i>	Artifact	references identifies the Artifact that specifies and/or enhances the definition of this entity.
related to	<i>relates</i>	Action	related to identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
relates	<i>related to</i>	Action	relates identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
resolves	<i>resolved by</i>	Risk	resolves identifies the Risk that is closed by this entity.
results in	<i>result of</i>	Decision	results in identifies the Decision that is caused by this entity.

Relationship	Inverse	Target Entity	Description
<i>seizes</i>	<i>seized by</i>	Resource	<i>seizes</i> identifies the Resource that this Action uses. After this Action has completed the Resource is released for use by other Actions .
	Attribute	Type	Description
	<u>amount</u>	Number	<u>amount</u> represents how much of the resource is <i>captured by</i> the Action . Units are relative to the units selected for the Resource .
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.

3.4.2 Artifact

Entity	Parent Class	Child Entities	Description
Artifact	None	None	An Artifact entity specifies a document or other source of information that is referenced by or generated in the knowledgebase. Example: Requirements Report.

Attribute	Type	Description
<i>date published</i>	DateTime	<i>date published</i> represents the date when this Artifact was accessed (webpage), published, or uploaded to the knowledgebase.
<i>file</i>	URI	The <i>file</i> that represents this Artifact .
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Artifact these can include: Briefing, Change Notice, Change Request, Concept of Operations, Directive, Doctrine, Document, E-Mail, Guidance, Instruction, Interface Control Document, Interface Requirements Specification, Manual, Matrix, Meeting Minutes, Memorandum, Mitigation Plan, Model, Operational Concept, Policy, Procedure, Protocol, Proposal, Regulation, Requirements Document, Request for Proposals, Software Requirements Specification, Standard, System Requirements Document, System/Segment Design Document, System/Segment Specification, Test & Evaluation Plan, Test & Evaluation Report, Text Message, Trade Study, White Paper

Relationship	Inverse	Target Class(es)	Description
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
decomposed by	decomposes	Artifact	decomposed by identifies the children of this entity.
decomposes	decomposed by	Artifact	decomposes identifies the parent of this entity.
defines protocol for	defined protocol by	Conduit	defines protocol for identifies the Conduit that uses the standard identified in this Artifact .
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
located at	locates	Location	located at identifies the Location where this entity exists.
mitigates	mitigated by	Risk	mitigates identifies the Risk that this entity plan alleviates.

<i>occurs</i>	<i>occurred by</i>	Time	<i>occurs</i> identifies the Time (or timespan) this entity happens.
<i>referenced by</i>	<i>references</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Input/Output, Risk, Statement	<i>referenced by</i> identifies the entity that specified and/or enhanced its definition by this Artifact .
<i>related to</i>	<i>relates</i>	Artifact	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	<i>Attribute</i>	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>relates</i>	<i>related to</i>	Artifact	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	<i>Attribute</i>	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>source of</i>	<i>sourced by</i>	Statement	<i>source of</i> identifies the Statement that is contained in this Artifact .
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.

3.4.3 Asset

Entity	Parent Entity	Child Entities	Description
<i>Asset</i>	None	Resource	An <i>Asset</i> entity specifies an object, person, or organization that used to create value and perform Actions , such as a system, subsystem, component, or element. Example: Infrared Sensor, Accounting Department, Internal Revenue Service

Attribute	Type	Description
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Asset these can include: Architecture, Assembly, Component, Context, CSC, CSCI, CSU, Element, Environment, External System, Facility, Hardware, Human, HW Element, HWCI, Infrastructure, LRU, Materiale, Operational Element, Organization, Part, Performer, Personnel, Segment, Service, Software, Subassembly, Subsystem, System, System Instantiation, Test Equipment, Test Software, Unit

Relationship	Inverse	Target Entity(es)	Description
<i>causes</i>	<i>caused by</i>	Risk	<i>causes</i> identifies the Risk resulting from this entity.
<i>connected by</i>	<i>connects to</i>	Connection	<i>connected by</i> identifies the Connection that adjoins this Asset .
	Attribute	Type	Description
	<u>origin</u>	Boolean	<u>origin</u> represents if the Asset is the origin of the Connection . This attribute enables unidirectional (one or the other Asset 's relationship <u>origin</u> is false), in addition to the default bi-directional flow (both <u>origins</u> are set to true as a default).
	<u>multiplicity</u>	Text	<u>multiplicity</u> , also called cardinality, represents the number of relationships (one to many, many to one, etc.) that can occur.
<i>decomposed by</i>	<i>decomposes</i>	Asset	<i>decomposed by</i> identifies the children of this entity.
<i>decomposes</i>	<i>decomposed by</i>	Asset	<i>decomposes</i> identifies the parent of this entity.
<i>enables</i>	<i>enabled by</i>	Decision	<i>enables</i> identifies the Decision that is empowered by this entity.
<i>incurs</i>	<i>incurred by</i>	Cost	<i>incurs</i> identifies the Cost value for this entity.
<i>located at</i>	<i>locates</i>	Location	<i>located at</i> identifies the Location where this entity exists.

made	made by	Decision	made identifies the Decision that this Asset decided.
mitigates	mitigated by	Risk	mitigates identifies the Risk that this entity plan alleviates.
occurs	occurred by	Time	occurs identifies the Time (or timespan) this entity happens.
orbited by	orbits	Asset	orbited by identifies Asset entity that acts as a satellite to this Asset .
orbits	orbited by	Asset	orbits identifies the Asset that this Asset moves around.
performs	performed by	Action	performs identifies the Action that is executed by this Action .
references	referenced by	Artifact	references identifies the Artifact that specifies and/or enhances the definition of this entity.
related to	relates	Asset	related to identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
relates	related to	Asset	relates identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
resolves	resolved by	Risk	resolves identifies the Risk that is closed by this entity.
responds to	responded by	Decision	responds to identifies the Decision that is acted on by this Asset (usually a person or organization).
	Attribute	Type	Description
	<u>responsibility</u>	Enumeration [Primary, Secondary]	<u>responsibility</u> represents the Asset that has the responsibility for resolving the Decision .
results in	result of	Decision	results in identifies the Decision that is caused by this entity.
specified by	specifies	Characteristic	specified by identifies a Characteristic that provides further information about this entity.
traced from	traced to	Statement	traced from identifies a Statement that accredited to this entity.

3.4.4 Characteristic

Entity	Parent Entity	Child Entities	Description
Characteristic	None	Measure	A Characteristic entity specifies properties of an entity. Examples: Blue, no heavier than 2 oz, accurate to within 1%

Attribute	Type	Description
<i>units</i>	Text	<i>units</i> represents this Characteristic 's units used to measure the value, such as ponds or miles per hour.
<i>value</i>	Text	<i>value</i> represents this Characteristic 's current value.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Characteristic these can include: Condition, Data Element, Environmental, Functional, Performance, Physical, Scenario, Security, Verification Category

Relationship	Inverse	Target Entity(es)	Description
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
decomposed by	decomposes	Characteristic	decomposed by identifies the children of this entity.
decomposes	decomposed by	Characteristic	decomposes identifies the parent of this entity.
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
located at	locates	Location	located at identifies the Location where this entity exists.
mitigates	mitigated by	Risk	mitigates identifies the Risk that this entity plan alleviates.
occurs	occurred by	Time	occurs identifies the Time (or timespan) this entity happens.
references	referenced by	Artifact	references identifies the Artifact that specifies and/or enhances the definition of this entity.
related to	relates	Characteristic	related to identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.

<i>relates</i>	<i>related to</i>	Characteristic	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<i>context</i> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>specifies</i>	<i>specified by</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Input/Output, Location, Risk, Statement, Time	<i>specifies</i> identifies an entity that this Characteristic provides further information about.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.

3.4.5 Conduit (Connection)

Entity	Parent Entity	Child Entities	Description
Conduit	Connection	None	A Conduit entity specifies the connection between Assets and has capacity and latency, which carries an Input/Output. Examples: Spacewire, Bluetooth, railway

Attribute	Type	Description
<i>capacity</i>	Number	<i>capacity</i> represents the maximum rate supported by the Conduit . (Used in simulation as to add time delay by dividing the Input/Output size with the <i>capacity</i> value.)
<i>latency</i>	Number	<i>latency</i> represents the time required to transmit the information or Input/Output entity over this Conduit . This value does not factor in any delays due to capacity limitations.
<i>units</i>	Text	<i>units</i> represents this Conduit 's units used to measure the capacity, such as bits per second or gallons per minute.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Conduit these can include: Cable, Downlink, Human-in-the-Loop, Human Machine Interface, Interface, Landline, Link, Needline, Network, Pipe, RF - Satcom, RF - Terrestrial, Roadway, Service Interface, Uplink, Wireless.

Relationship	Inverse	Target Entity(es)	Description
<i>decomposed by</i>	<i>decomposes</i>	Conduit	<i>decomposed by</i> identifies the children of this entity.
<i>decomposes</i>	<i>decomposed by</i>	Conduit	<i>decomposes</i> identifies the parent of this entity.
<i>defined protocol by</i>	<i>defines protocol for</i>	Artifact	<i>defined protocol by</i> identifies the Artifact that contains the standard used by this Conduit .
<i>transfers</i>	<i>transferred by</i>	Input/Output	<i>transfers</i> identifies the Input/Output that is passed by this Conduit .

All attributes and relationships from **Connection** are inherited by the **Conduit** entities.

3.4.6 Connection

Entity	Parent Entity	Child Entities	Description
Connection	None	Conduit, Logical	A Connection entity specifies the mechanism relating Assets. This is an abstract class.

Relationship	Inverse	Target Entity(es)	Description
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
connects to	connected by	Asset	connects to identifies the Asset that this <i>Connection</i> adjoins.
	Attribute	Type	Description
	<u>origin</u>	Boolean	<u>origin</u> represents if the Asset is the origin of the <i>Connection</i> . This attribute enables unidirectional (one or the other Asset 's relationship <u>origin</u> is False), in addition to the default bi-directional flow (both <u>origins</u> are set to True as a default).
	<u>multiplicity</u>	Text	<u>multiplicity</u> , also called cardinality, represents the number of relationships (one to many, many to one, etc.) that can occur.
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
joined by	joins	Connection	joined by identifies the Connection that connects to this Connection . joined by implies the end of the relationship.
	Attribute	Type	Description
	<u>bidirectional</u>	Boolean	<u>bidirectional</u> represents if the connection between two Connections is bidirectional. If the Connection is not bidirectional the <i>Connection</i> that has the relation joins is the start and the Connection with joined by is the end.

<i>joins</i>	<i>joined by</i>	Connection	<i>joins</i> identifies the Connection that is connected to this Connection . <i>Joins</i> implies the start of this relationship.
	Attribute	Type	Description
	<u>bidirectional</u>	Boolean	<u>bidirectional</u> represents if the connection between two Connections is bidirectional. If the Connection is not bidirectional the Connection that has the relation <i>joins</i> is the start and the Connection with <i>joined by</i> is the end.
<i>located at</i>	<i>locates</i>	Location	<i>located at</i> identifies the Location where this entity exists.
<i>mitigates</i>	<i>mitigated by</i>	Risk	<i>mitigates</i> identifies the Risk that this entity plan alleviates.
<i>occurs</i>	<i>occurred by</i>	Time	<i>occurs</i> identifies the Time (or timespan) this entity happens.
<i>references</i>	<i>referenced by</i>	Artifact	<i>references</i> identifies the Artifact that specifies and/or enhances the definition of this entity.
<i>related to</i>	<i>relates</i>	Connection	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>relates</i>	<i>related to</i>	Connection	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.

3.4.7 Cost

Entity	Parent Entity	Child Entities	Description
Cost	None	None	A Cost entity specifies the outlay or expenditure (as of effort or sacrifice) made to achieve an objective associated with another entity. Examples: \$100, 6 man-hours

Attribute	Type	Description
<i>amount</i>	Number	<i>amount</i> represents this Cost 's value.
<i>category</i>	Enumeration [Procurement, MILCON, MILPERS, O&M, RDT&E, SCN, N/A]	<i>category</i> represents the part of the lifecycle for which the money is used (commonly called Color of Money). This matches the Federal Government (DoD) cost phases.
<i>contract type</i>	Enumeration [CPFF, CPAF, CPIF, FFP-Completion, FFP-LOE, T&M, N/A]	<i>contract type</i> represents this Cost way to identify the reimbursement structure (i.e. CPFF vs T&M).
<i>rate</i>	Enumeration [Fixed , Per Hour]	<i>rate</i> represents this Cost 's billing rate.
<i>units</i>	Text	<i>units</i> represents this Cost 's units used to measure the amount, such as \$ or Euro.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Cost these can include: Actual, Earned Value, Estimated, Overrun, Plan

Relationship	Inverse	Target Entity(es)	Description
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
decomposed by	decomposes	Cost	decomposed by identifies the children of this entity.
decomposes	decomposed by	Cost	decomposes identifies the parent of this entity.
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
incurred by	incurs	Action, Artifact, Asset, Characteristic, Connection, Decision, input/Output, Risk, Statement	incurred by identifies the entity that has this Cost value.

<i>located at</i>	<i>locates</i>	Location	<i>located at</i> identifies the Location where this entity exists.
<i>mitigates</i>	<i>mitigated by</i>	Risk	<i>mitigates</i> identifies the Risk that this entity plan alleviates.
<i>occurs</i>	<i>occurred by</i>	Time	<i>occurs</i> identifies the Time (or timespan) this entity happens.
<i>references</i>	<i>referenced by</i>	Artifact	<i>references</i> identifies the Artifact that specifies and/or enhances the definition of this entity.
<i>related to</i>	<i>relates</i>	Cost	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>relates</i>	<i>related to</i>	Cost	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.

3.4.8 Decision

Entity	Parent Entity	Child Entities	Description
Decision	None	None	A Decision entity specifies an opportunity to make a choice. Examples: slip schedule by two months, accept risk, hire ten new employees

Attribute	Type	Description
<i>assumptions</i>	Text	<i>assumptions</i> represents facts that are used as a basis for this Decision . These assumptions can be taken for granted by the decision maker.
<i>justification</i>	Text	<i>justification</i> represents the reason and context for making this Decision . For additional justification, the user may want to apply the enabled by relationship to link it to other Statements .
<i>status</i>	Enumeration [Open, Closed]	<i>status</i> represents the state of the Decision (open or closed).
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Decision these can include: Challenge, Issue, Problem.

Relationship	Inverse	Target Entity(es)	Description
alternative	alternative of	Statement	alternative identifies the Statement that is a potential choice for this Decision .
	Attribute	Type	Description
	<u>choice</u>	Boolean	<u>choice</u> represents if this alternative was the choice selected. If the Decision is still open none of these alternatives would be True.
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
date resolved by	date resolves	Time	date resolved by identifies the Time when this Decision was closed. For open issues this attribute can be left blank.
decomposed by	decomposes	Decision	decomposed by identifies the children of this entity.
decomposes	decomposed by	Decision	decomposes identifies the parent of this entity.
decision due	decided by	Time	decision due identifies the Time when this Decision is scheduled to be closed.

<i>enabled by</i>	<i>enables</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Input/Output, Risk, Statement	<i>enabled by</i> identifies the entity that empowers this Decision to be made.
<i>incurs</i>	<i>incurred by</i>	Cost	<i>incurs</i> identifies the Cost value for this entity.
<i>located at</i>	<i>locates</i>	Location	<i>located at</i> identifies the Location where this entity exists.
<i>made by</i>	<i>made</i>	Asset	<i>made by</i> identifies the Asset that made this <i>Decision</i> .
<i>mitigates</i>	<i>mitigated by</i>	Risk	<i>mitigates</i> identifies the Risk that this entity plan alleviates.
<i>occurs</i>	<i>occurred by</i>	Time	<i>occurs</i> identifies the Time (or timespan) this entity happens.
<i>references</i>	<i>referenced by</i>	Artifact	<i>references</i> identifies the Artifact that specifies and/or enhances the definition of this entity.
<i>related to</i>	<i>relates</i>	Decision	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>relates</i>	<i>related to</i>	Decision	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the <i>Risk</i> that is closed by this entity.
<i>responded by</i>	<i>responds to</i>	Asset	<i>responded by</i> identifies the Asset (usually a person or organization) that acts on this Decision .
	Attribute	Type	Description
	<i>responsibility</i>	Enumeration [Primary, Secondary]	<i>responsibility</i> represents the Asset that has the responsibility for resolving the Decision .

<i>result of</i>	<i>results in</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Input/Output, Risk, Statement	<i>result of</i> identifies the entity that caused this Decision .
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that this Decision comes from.

3.4.9 Input/Output

Entity	Parent Entity	Child Entities	Description
Input/Output	None	None	An Input/Output entity specifies the matter, energy, and/or information input to, triggers (controls), or output from an Action. Examples: Nickel/gumball, gasoline/horsepower, investment/return

Attribute	Type	Description
<i>size</i>	Number	<i>size</i> represents the amount or proportion of this Input/Output , such as 100 as 100 Gigabytes or number of entities (e.g. 10 as in 10 tokens).
<i>units</i>	Text	<i>units</i> represents this Input/Output 's units used to measure the size such as Gigabytes or tokens.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Input/Output these can include: Analog, Data, Digital, Event, Information, Item, Mixed, Physical, Product, Verbal.

Relationship	Inverse	Target Entity(es)	Description
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
decomposed by	decomposes	Input/Output	decomposed by identifies the children of this entity.
decomposes	decomposed by	Input/Output	decomposes identifies the parent of this entity.
enables	enabled by	Decision	enables identifies the Decision that was empowered by this entity.
generated by	generates	Action	generated by identifies the Action that this Input/Output was transformed by.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
located at	locates	Location	located at identifies the Location where this entity exists.
mitigates	mitigated by	Risk	mitigates identifies the Risk that this entity plan alleviates.
occurs	occurred by	Time	occurs identifies the Time (or timespan) this entity happens.

<i>received by</i>	<i>receives</i>	Action	<i>received by</i> identifies the Action that takes in this <i>Input/Output</i> .
	Attribute	Type	Description
	<u>trigger</u>	Boolean	<u>trigger</u> represents this relation as an enabling requirement for the Action . An Action begins execution when it has received control enablement, all of its <u>triggers</u> have arrived, and its necessary resources are available.
<i>references</i>	<i>referenced by</i>	Artifact	<i>references</i> identifies the Artifact that specifies and/or enhances the definition of this entity.
<i>related to</i>	<i>relates</i>	Input/Output	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>relates</i>	<i>related to</i>	Input/Output	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.
<i>transferred by</i>	<i>transfers</i>	Connection	<i>transferred by</i> identifies the Connection that passes this Input/Output .

3.4.10 Location

Entity	Parent Entity	Child Entities	Description
Location	None	Orbital, Physical, Virtual	A Location entity specifies where an entity resides. Abstract Class.

Relationship	Inverse	Target Entity(es)	Description
<i>decomposed by</i>	<i>decomposes</i>	Location	<i>decomposed by</i> identifies the children of this entity.
<i>decomposes</i>	<i>decomposed by</i>	Location	<i>decomposes</i> identifies the parent of this entity.
<i>locates</i>	<i>located at</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Input/Output, Statement	<i>locates</i> identifies an entity that exists at this Location .
<i>mitigates</i>	<i>mitigated by</i>	Risk	<i>mitigates</i> identifies the Risk that this entity plan alleviates.
<i>occurs</i>	<i>occurred by</i>	Time	<i>occurs</i> identifies the Time (or timespan) this entity happens.
<i>related to</i>	<i>relates</i>	Location	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>relates</i>	<i>related to</i>	Location	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced from</i>	<i>traced to</i>	Statement	<i>traced from</i> identifies a Statement that accredited to this entity.

3.4.11 Logical (Connection)

Entity	Parent Entity	Child Entities	Description
Logical	Connection	None	A Logical entity specifies relationship between Assets. It is primarily used in database schema development and entity-relationship diagrams.

Relationship	Inverse	Target Entity(es)	Description
Note for <i>specified by</i> (see description)	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity. This relationship is used to specify an attribute on a relationship in an extended Entity-Relationship-Attribute (ERA) schema.

All attributes and relationships from **Connection** are inherited by the **Logical** entities.

3.4.12 *Measure (Characteristic)*

Entity	Parent Entity	Child Entities	Description
Measure	Characteristic	None	A Measure entity specifies the set of measurements used to provide managers, system developers, and systems engineers with insight into the system definition, the analysis of technical solutions with respect to performance, cost, and risk. Examples: 19 inches, 22 grams, 1.21 gigawatts

Attribute	Type	Description
<i>improvement direction</i>	Enumeration [N/A, Positive , Negative]	<i>improvement direction</i> represents the direction in that metric improvement occurs. It is the direction from the <i>threshold value</i> to the <i>objective value</i> .
<i>objective value</i>	Text	<i>objective value</i> represents the goal for this Measure .
<i>projected value</i>	Text	<i>projected value</i> represents this Measure 's expected value to be achieved with existing resources.
<i>threshold value</i>	Text	<i>threshold value</i> represents the minimum acceptable value for this Measure .
<i>tolerance</i>	Text	<i>tolerance</i> represents the percentage of the value that forms the positive and negative tolerance bands. <i>tolerance</i> is used when <i>value</i> represents the planned measure value at a given time.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Measure these can include: Critical Operational Issue (COI), Key Performance Parameter (KPP), Mean Time Between Failures (MTBF), Measure of Effectiveness (MOE), Measure of Performance (MOP), Metric, Technical Performance Measure (TPM).

All attributes and relationships from **Characteristic** are inherited by the **Measure** entities.

3.4.13 *Orbital (Location)*

Entity	Parent Entity	Child Entities	Description
Orbital	Location	None	An Orbital entity specifies a location (ephemeris) along an orbit around a celestial body. Note that this includes transfer orbits as well. Examples: Mars orbit, transfer to lunar orbit

Attribute	Type	Description
<i>Inclination</i>	Number	<i>inclination</i> represents the angle between the orbital plane and a reference plane, such as the equatorial plane for Earth. The <i>Inclination</i> must be specified with the <i>longitude of ascending node</i> to characterize the orbital plane.
<i>Semimajor Axis</i>	Number	<i>semimajor axis</i> represents the one half of the length of the longest diameter of the orbital ellipse. The <i>semimajor axis</i> must be specified with the <i>eccentricity</i> to characterize the orbital ellipse shape.
<i>Longitude of Ascending Node</i>	Number	<i>longitude of ascending node</i> represents the angle from the <i>origin of longitude</i> to the ascending node, measured in the <i>reference plane</i> . For the Earth, the <i>origin of longitude</i> is typically the Prime Meridian. The <i>longitude of ascending node</i> must be specified with the <i>Inclination</i> to characterize the orbital plane.
<i>Reference Plane</i>	Text	<i>reference plane</i> represents the reference plane from where the Inclination angle will be calculated.
<i>Argument of Periapsis</i>	Number	<i>argument of periapsis</i> represents the angle between the Periapsis and the ascending node as measured in the orbital plane in the direction of motion.
<i>Origin of Longitude</i>	Text	<i>origin of longitude</i> represents the reference meridian from where the <i>longitude of ascending node</i> will be calculated.
<i>Mean Anomaly</i>	Number	<i>mean anomaly</i> represents the proportion of orbital area swept since the last <i>periapsis</i> at the specified time. It is used to define the position of the orbiting Asset along the orbital ellipse.
<i>Apoapsis</i>	Number	<i>apoapsis</i> represents the point of greatest distance from the celestial body being orbited. For Earth, the term is apogee. For the Sun the term commonly used is aphelion. The <i>apoapsis</i> must be specified with the <i>periapsis</i> to characterize the orbital ellipse shape.
<i>Periapsis</i>	Number	<i>periapsis</i> represents the point of closest distance from the celestial body being orbited. For Earth, the term is perigee. For the Sun the term commonly used is perihelion. The <i>periapsis</i> must be specified with the <i>apoapsis</i> to characterize the orbital ellipse shape.
<i>Eccentricity</i>	Number	<i>eccentricity</i> represents the amount the orbit deviates from a perfect circle (0 being perfectly circular and 1 is a parabola - no longer a closed orbit). The <i>eccentricity</i> must be specified with the <i>semimajor axis</i> to characterize the orbital ellipse shape.

All attributes and relationships from **Location** are inherited by the **Orbital** entities.

3.4.14 *Physical (Location)*

Entity	Parent Entity	Child Entities	Description
Physical	Location	None	A Physical entity specifies a location on, below, or above the surface of a celestial body. Examples: North Pole, Camp Lejeune

Attribute	Type	Description
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Physical these can include: Geospatial Location, Map Coordinates

Attribute	Data Type	Description
<i>address</i>	Text	<i>address</i> represents this Location's complete address.
<i>altitude/depth</i>	Number	<i>altitude/depth</i> represents the distance above (positive values) or below (negative values) the surface.
<i>coordinates</i>	GeoPoint	<i>coordinates</i> represents the coordinate points for this Location (GPS or other system).
<i>units</i>	Text	<i>units</i> represents the units used to measure the <i>altitude/depth</i> of the Physical location.

Note that this entity definition uses Cartesian Coordinates (x, y, z). It may be desirable to establish other coordinate systems (e.g., Cylindrical, Spherical, etc.) for other implementations.

All attributes and relationships from **Location** are inherited by the **Physical** entities.

3.4.15 Requirement

Entity	Parent Entity	Child Entities	Description
Requirement	Statement	None	A Requirement entity identifies a capability, characteristic, or quality factor of a system that must exist for the system to have value and utility to the user. Example: pump shall weigh no more than 1.2 kilograms.

Attribute	Type	Description
<i>rationale</i>	Text	<i>rationale</i> provides a place to capture the reason(s) behind this Requirement .
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Requirement these can include: Functional Requirement, Safety Requirement, Support Requirement, Verification Requirement

Note the quality attributes below are optional. Other sets of quality attributes may be provided by the tool developer or these may be user-definable. However, some form of quality attributes are recommended.

Attribute	Type	Description
<i>clear</i>	Boolean	<i>clear</i> represents if this Requirement is unambiguous and not confusing.
<i>complete</i>	Boolean	<i>complete</i> represents if this Requirement expresses a whole idea.
<i>consistent</i>	Boolean	<i>consistent</i> represents if this Requirement is not in conflict with other requirements.
<i>correct</i>	Boolean	<i>correct</i> represents if this Requirement describes the user's true intent and is legally possible.
<i>design</i>	Boolean	<i>design</i> represents if this Requirement does not impose a specific solution on design; says "what", not "how".
<i>feasible</i>	Boolean	<i>feasible</i> represents if this Requirement is able to be implemented with existing technology, and within cost and schedule.
<i>modular</i>	Boolean	<i>modular</i> represents if this Requirement can be changed without excessive impact on other requirements.
<i>traceable</i>	Boolean	<i>traceable</i> represents if this Requirement is uniquely identified, and able to be tracked to predecessor and successor lifecycle items/objects.
<i>verifiable</i>	Boolean	<i>verifiable</i> represents if this Requirement is provable (within realistic cost and schedule) that the system meets the requirement.

All attributes and relationships from **Statement** are inherited by the **Requirement** entities.

3.4.16 Resource

Entity	Parent Entity	Child Entities	Description
Resource	Asset	None	A Resource entity specifies a consumable or producible Asset . Example: \$5, 2 kilowatts, natural gas

Attribute	Type	Description
<i>initial amount</i>	Number	<i>initial amount</i> represents this Resource 's starting amount.
<i>maximum amount</i>	Number	<i>maximum amount</i> represents this Resource 's maximum amount allowed.
<i>minimum amount</i>	Number	<i>minimum amount</i> represents this Resource 's minimum amount allowed.
<i>units</i>	Text	<i>units</i> represents this Resource 's units used to measure the amounts, such as each or tons.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Resource these can include: Computer Resource, Human Resource, Fuel

Relationship	Inverse	Target Entity(es)	Description
<i>consumed by</i>	<i>consumes</i>	Action	<i>consumed by</i> identifies the Action that uses this Resource . After the Action is completed the amount consumed is not returned to the Resource .
	Attribute	Type	Description
	<u>amount</u>	Number	<u>amount</u> represents how much of the resource is <i>consumed by</i> the Action . Units are relative to the units selected for the Resource .
<i>produced by</i>	<i>produces</i>	Action	<i>produced by</i> identifies the Action that creates this Resource . Resources are produced when the execution of the action completes.
	Attribute	Type	Description
	<i>amount</i>	Number	<i>amount</i> represents how much of the <i>Resource</i> is <i>produced by</i> the <i>Action</i> . Units are relative to the units selected for the <i>Resource</i> .

<i>seized by</i>	<i>seizes</i>	Action	<i>seized by</i> identifies the Action that uses this Resource . After the Action has completed this Resource is released for use by other Actions .
	Attribute	Type	Description
	<u>amount</u>	Number	<u>amount</u> represents how much of the resource is <i>captured by</i> the Action . Units are relative to the units selected for the Resource .

All attributes and relationships from **Asset** are inherited by the **Resource** entities.

3.4.17 Risk

Entity	Parent Entity	Child Entities	Description
Risk	None	None	A Risk entity specifies the combined probability and consequence in achieving objectives. Example: the risk of a large meteorite hitting the earth in the next 100 years is low but that could cause the extinction of life as we know it.

Attribute	Type	Description
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Risk these can include: Cost Risk, Schedule Risk, Technical Risk

Attribute	Type	Description
<i>consequence</i>	Percent	<i>consequence</i> represents the level of effect from this Risk occurring.
<i>consequence description</i>	Text	<i>consequence description</i> represents the result of this Risk occurring.
<i>mitigation status</i>	Enumeration [Accept , Avoid, Mitigate, Transfer]	<i>mitigation status</i> represents the status of the mitigation technique for this Risk .
<i>probability</i>	Percent	<i>probability</i> or likelihood represents the chance that this Risk will occur.
<i>status</i>	Enumeration [Open , Duplicate, Declined, Resolved]	<i>status</i> represents the current state of this Risk .
<i>trend</i>	Enumeration [Decreasing, Increasing, New, Unchanged]	<i>trend</i> indicates the change in the Risk over time as to whether it is increasing or decreasing or staying the same.

Relationship	Inverse	Target Entity(es)	Description
<i>caused by</i>	<i>causes</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Input/Output, Risk, Statement	<i>caused by</i> identifies the entity that this Risk results.

causes	caused by	Risk	causes identifies the Risk resulting from this entity.
decomposed by	decomposes	Risk	decomposed by identifies the children of this entity.
decomposes	decomposed by	Risk	decomposes identifies the parent of this entity.
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
located at	locates	Location	located at identifies the Location where this entity exists.
mitigated by	mitigates	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Location, Statement, Time	Mitigated by identifies the entity that contains the plan to alleviate this Risk .
occurs	occurred by	Time	occurs identifies the Time (or timespan) this entity happens.
references	referenced by	Artifact	references identifies the Artifact that specifies and/or enhances the definition of this entity.
related to	relates	Risk	related to identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
relates	related to	Risk	relates identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
resolved by	resolves	Action, Artifact, Asset, Characteristic, Connection, Cost, Decision, Input/Output, Risk, Statement	resolved by identifies the entity that closes this Risk .

<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.

3.4.18 Statement

Entity	Parent Entity	Child Entities	Description
Statement	None	Requirement	A Statement entity specifies text referenced by the knowledgebase and usually contain in an Artifact. Example: Elvis is king!, Our goal is to be the first on Mars

Attribute	Type	Description
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Statement these can include: Acronym, Assumption, Constraint, Definition, Directive, Doctrine, Goal, Need, Objective, Plan, Policy, Question, Rule, Scope, Standard, Vision

Relationship	Inverse	Target Entity(es)	Description
alternative of	alternative	Decision	alternative of identifies the <i>Decision</i> that has this <i>Statement</i> as a potential choice.
	Attribute	Type	Description
	<u>choice</u>	Boolean	<u>choice</u> represents if this alternative was the choice selected.
causes	caused by	Risk	causes identifies the Risk resulting from this entity.
decomposed by	decomposes	Statement	decomposed by identifies the children of this entity.
decomposes	decomposed by	Statement	decomposes identifies the parent of this entity.
enables	enabled by	Decision	enables identifies the Decision that is empowered by this entity.
incurs	incurred by	Cost	incurs identifies the Cost value for this entity.
located at	locates	Location	located at identifies the Location where this entity exists.
mitigates	mitigated by	Risk	mitigates identifies the Risk that this entity plan alleviates.
occurs	occurred by	Time	occurs identifies the Time (or timespan) this entity happens.
references	referenced by	Artifact	references identifies the Artifact that specifies and/or enhances the definition of this entity.
related to	relates	Statement	related to identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.

<i>relates</i>	<i>related to</i>	Statement	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.
<i>resolves</i>	<i>resolved by</i>	Risk	<i>resolves</i> identifies the Risk that is closed by this entity.
<i>results in</i>	<i>result of</i>	Decision	<i>results in</i> identifies the Decision that is caused by this entity.
<i>sourced by</i>	<i>source of</i>	Artifact	<i>sourced by</i> identifies the Artifact that contains this <i>Statement</i> .
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.
<i>traced to</i>	<i>traced from</i>	Action, Artifact, Asset, Characteristic, Connection, Cost, Input/Output, Location	<i>traced to</i> identifies an entity that is accredited to this Statement .

3.4.19 Time

Entity	Parent Entity	Child Entities	Description
Time	None	None	A Time entity specifies a point or period when an action, asset, process, or condition exists, finishes, starts, or continues. Example: Milestone A, Phase 2

Attribute	Type	Description
<i>duration</i>	Number	<i>duration</i> represents the period of time this Time occurs. A zero (0) duration indicates a milestone.
<i>start</i>	DateTime	<i>start</i> represents the time when this Time begins.
<i>end</i>	DateTime	<i>end</i> represents the time when this Time finishes. It can be computed from the <i>start</i> and <i>duration</i> attributes.
<i>type</i>	Text	<i>type</i> provides aliases for the entities. For Time these can include: Duration, Milestone, Point In Time, Time Frame

Relationship	Inverse	Target Entity(es)	Description
<i>date resolves</i>	<i>date resolved by</i>	Decision	<i>date resolves</i> identifies the Decision that is closed at this Time .
<i>decided by</i>	<i>decision due</i>	Decision	<i>decided by</i> identifies the Decision scheduled for closure at this Time .
<i>decomposed by</i>	<i>decomposes</i>	Time	<i>decomposed by</i> identifies the children of this entity.
<i>decomposes</i>	<i>decomposed by</i>	Time	<i>decomposes</i> identifies the parent of this entity.
<i>mitigates</i>	<i>mitigated by</i>	Risk	<i>mitigates</i> identifies the <i>Risk</i> that this entity plan alleviates.
<i>occurred by</i>	<i>occurs</i>	Action, Artifact, Asset, Characteristic, Conduit, Cost, Decision, Input/Output, Location, Risk, Statement	<i>occurred by</i> identifies the entity that happens at this Time .
<i>related to</i>	<i>relates</i>	Time	<i>related to</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<u>context</u>	Text	<u>context</u> represents a description of this relation.

<i>relates</i>	<i>related to</i>	Time	<i>relates</i> identifies the entity that ties in a peer-to-peer way with this entity.
	Attribute	Type	Description
	<i>context</i>	Text	<i>context</i> represents a description of this relation.
<i>specified by</i>	<i>specifies</i>	Characteristic	<i>specified by</i> identifies a Characteristic that provides further information about this entity.

3.4.20 *Virtual (Location)*

Entity	Parent Entity	Child Entities	Description
Virtual	Location	None	A Virtual entity specifies a location within a digital network. Example: http://www.google.com

Attribute	Type	Description
<i>address</i>	URI	<i>address</i> represents the identification address using the Uniform Resource Identifier (URI) protocols.

All attributes and relationships from **Location** are inherited by the **Virtual** entities.

4 Visualizations

The following diagrams represent the common forms of visualization of information. They do not attempt to encompass all the possible visualizations. Only one is unique to LML: the Action Diagram. A number of similar models have been developed over the years to express functional sequencing, such as the Flow Charts, Activity Diagram in UML/SysML, Business Process Modeling Notation (BPMN), and others. Although these various notations are accurate, they use many different symbols, which often confuse the non-expert viewers or recipients of the visualization. As seen below, the visualization of this functional sequencing in LML is much simpler, but appears to have all the necessary information for language execution. The usual constructs are replaced by special cases of Actions to denote decision points.

The other visualizations should be considered standard diagrams, used over many years by different techniques. We also provide suggested diagrams that LML users may want consider as well. A few do not appear to require visualization beyond a hierarchy diagram. We denote which diagrams are appropriate for which classes.

4.1 Action Diagram (Mandatory for *Action* entities with children)

The Action Diagram (see Figure 4-1) represents the functional sequencing of **Actions** along with the data flow provided by the **Input/Output** entities. This combination of **Actions** with **Input/Outputs** is similar to the SREM “Behavior Diagram” or UML Activity Diagram. Without the **Input/Output** entities, the Action Diagram would be the equivalent of the classic Function Flow Block Diagram (FFBD) or IDEF 3. The main difference between LML and these other diagrams is the use of special kinds of **Actions** to replace the constructs used in these other languages. The construct set is shown below.

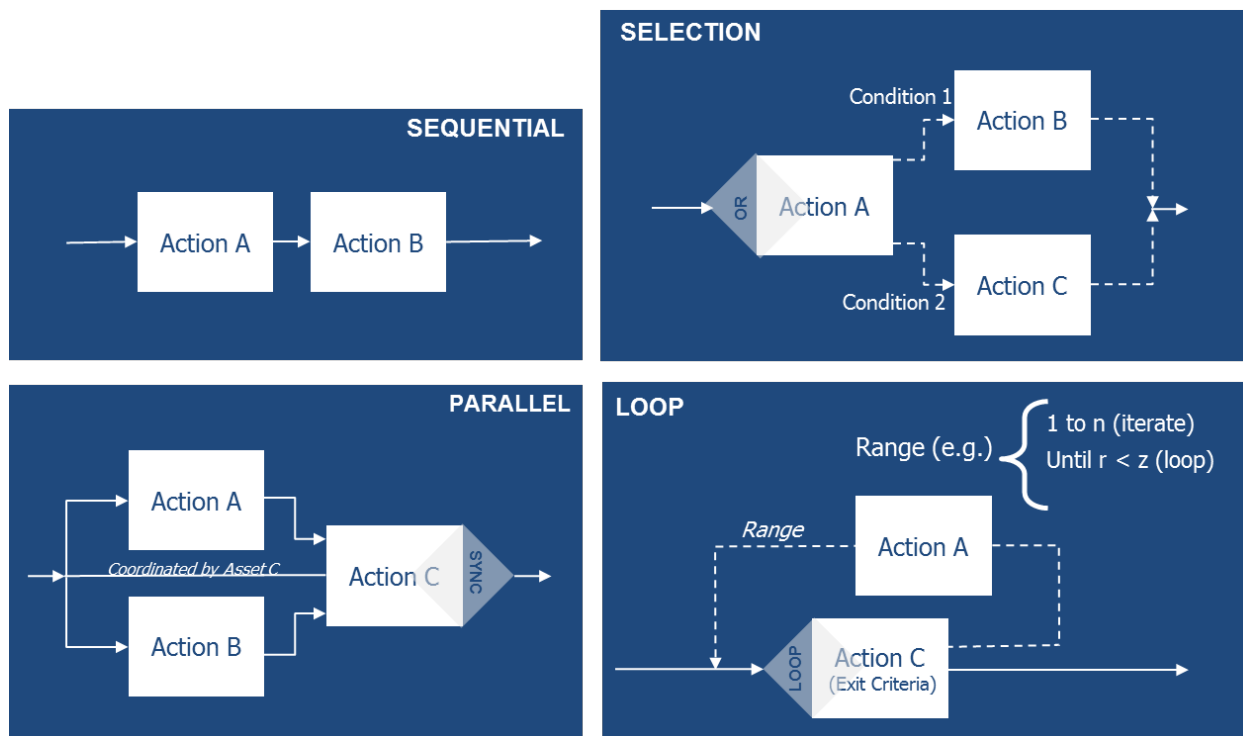


Figure 4-1. Special Actions for the Action Diagram to Capture Decision Points.

The special cases of **Actions**, denoted by the rectangle with a diamond embedded in it (showing $\frac{1}{2}$ the diamond as a point on the rectangle), represent decision points. For example, in a loop the key decision is the exit criteria for the loop. This criterion can be as simple as the number of iterations of the loop or more complex logic that determines when the loop must stop.

The “OR” decision point represents an exclusive selection of one path or the other. The decision point in the case can be a probability or a specific criterion for path selection.

The final decision point type is the “SYNC.” The SYNC provides the functional rationale for ending parallel branches. Note that in the physical view, two separate entities can exist without any synchronization between them. However, in the functional view between two physical entities that are interacting, it is necessary to decide how to terminate that interaction. We see this in software, when two parallel processes are spawned these threads must later be synchronized to complete the program.

The Action Diagram can include **Input/Output** entities as well. An example of this inclusion is shown in Figure 4-2.

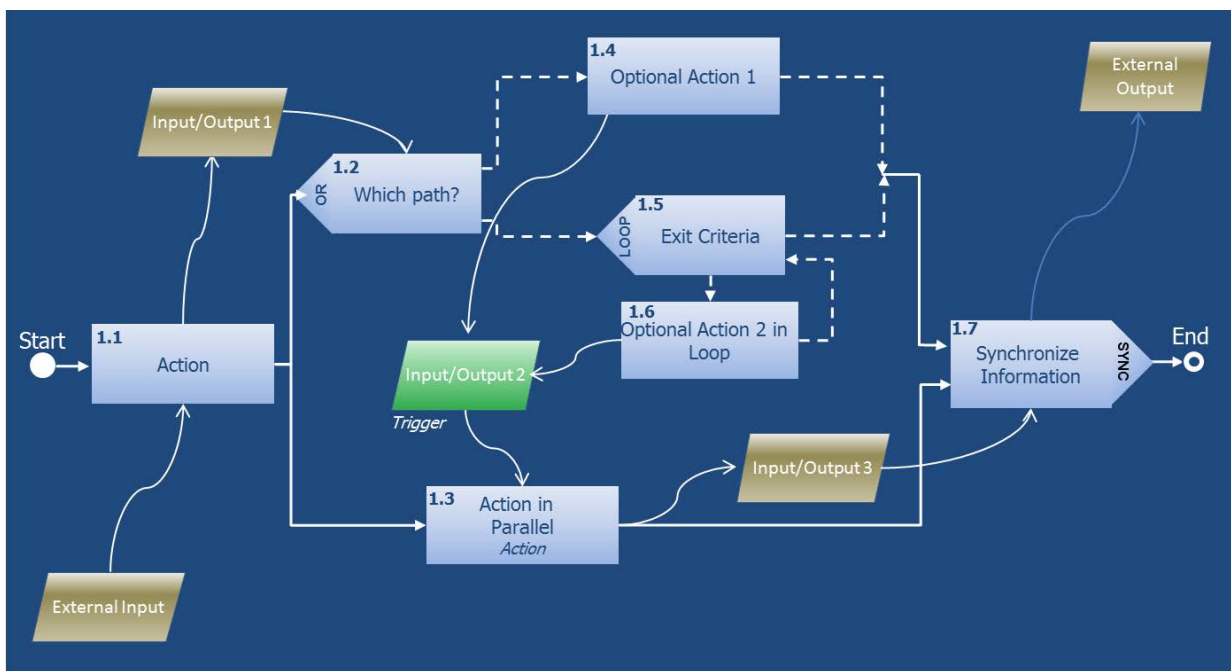


Figure 4-2. An Example Action Diagram with Inputs/Outputs.

The **Input/Output** entities are shown as parallelograms, reminiscent of the classical flow charting symbols used in the 1950s and 1960s. Two colors (or some other mechanism) are used to distinguish triggering **Input/Outputs** from optional **Input/Outputs**. It is recommended that a different type of line be used to show the **Input/Output** flow, thus making it easy to distinguish between the data flow and functional sequencing lines. The diagram should also contain a way to show the **Start** and **End** of the functional sequencing.

No other constructs have been determined to be necessary. Other languages include a “Replicate,” however the research done by the LML developers indicated that was a way identify a physical instantiation of the functional entity in more than one physical entity at a time. This representation appears more appropriately in the physical diagram (see Asset Diagram in next section).

While this specification does not directly specify or standardize the Action Diagram, the constructs above are to be used as guidance for the overall look of an Action Diagram. The key takeaway is the inclusion of logic flow into the Action entities themselves, instead of relying on separate logic flow diagram elements.

4.2 Asset Diagram (Mandatory for *Asset* entities with children)

LML must have a physical representation of design elements as well as the functional one provided by the Action Diagram. The Asset Diagram provides this kind of information. Figure 4-3 shows one way of providing this information. The **Assets** are shown as rectangles with **Conduits** displayed as lines connecting the **Assets**. Since **Resource** is a subclass of **Asset**, they could also be displayed by this diagram. Other information, such as the capacity and latency attributes of the **Conduit**, may be overlaid on this diagram as well. Also, since the **Asset** type may be of interest to most users it should be considered desirable to include that attribute on this diagram as well.

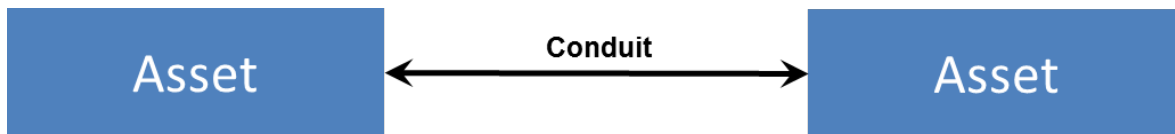


Figure 4-3. A Simple Asset Diagram.

Nodes and connections could be replaced with pictures as shown in Figure 4-4.

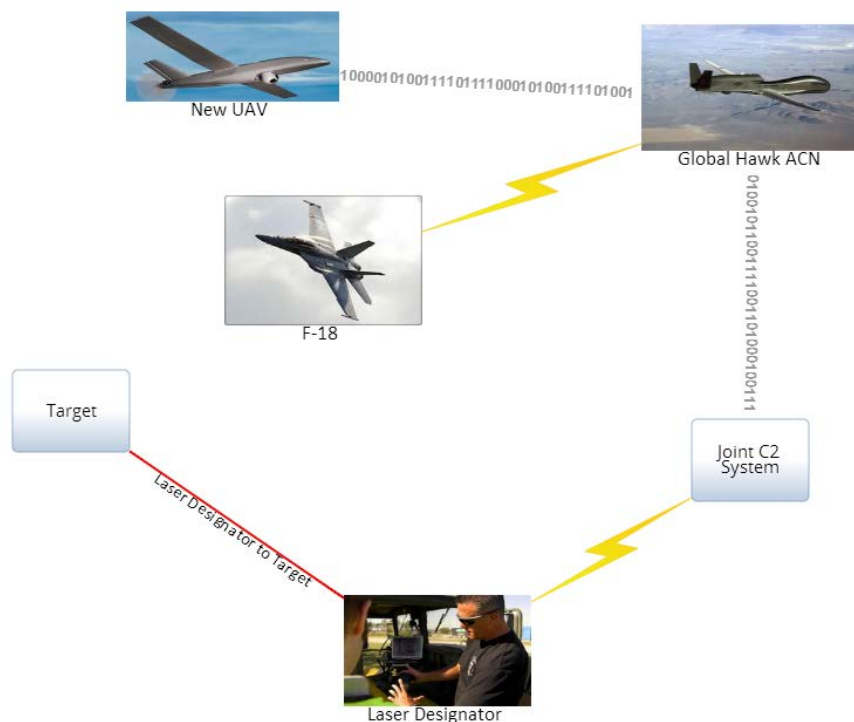


Figure 4-4. Asset Diagram with Pictures and Special Lines for Conduits.

The Asset Diagram is mandatory only for those Assets with children.

4.3 Spider Diagram (Mandatory for Traceability)

The spider diagram shows how entities are related to one another. This diagram is similar to the ERD shown above, but reflects LML's schema, not an abstract schema. This diagram (see Figure 4-5) shows traceability of LML entities with their relationships.

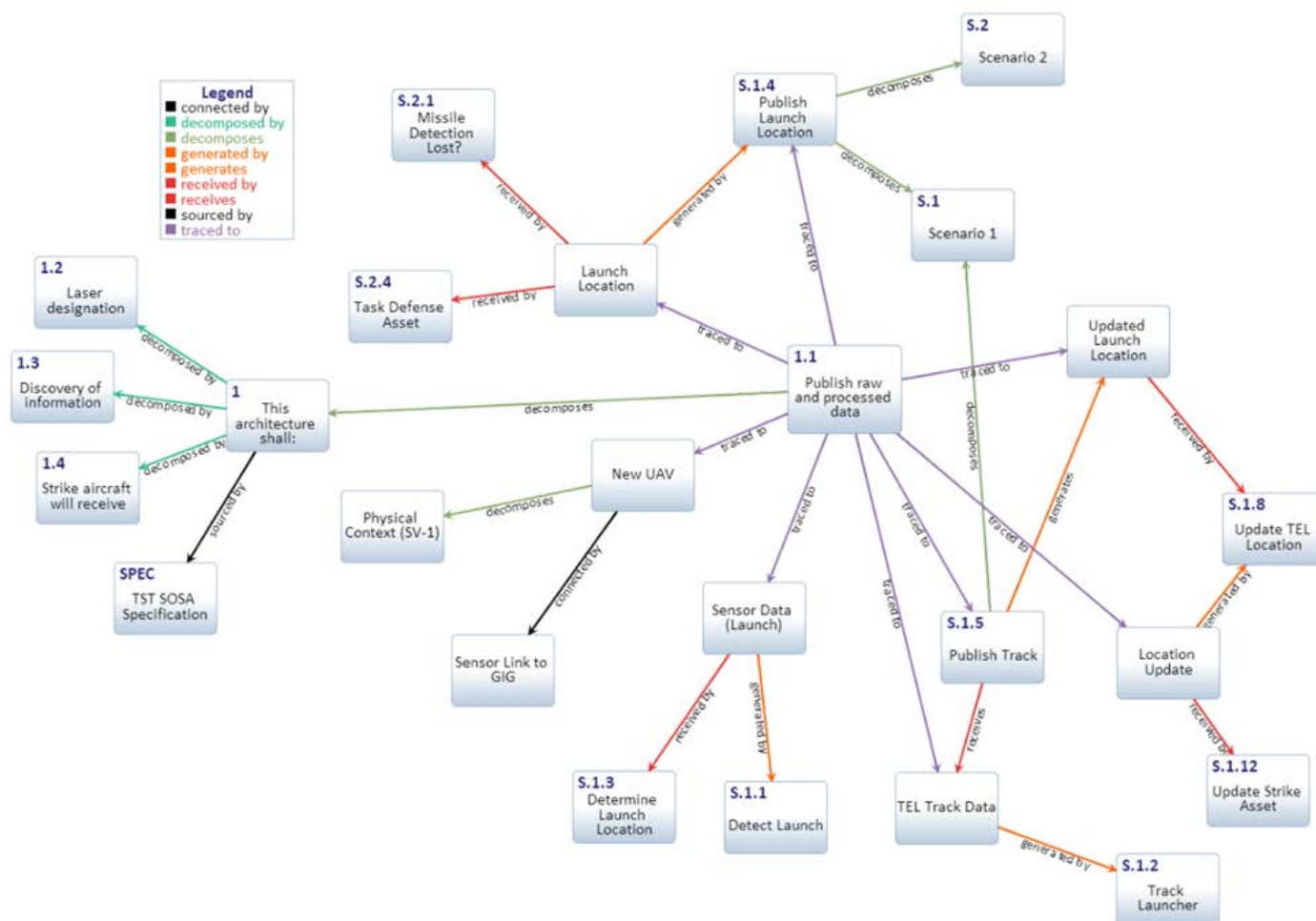


Figure 4-5. Example Spider Diagram to Show Traceability between Entities Using the LML Relationships.

4.4 Example Views for Other LML Entities

LML was designed to support the full lifecycle and all of its entities can support the common visualizations used by architects, systems engineers, software engineers, test engineers, operators, logisticians, and program managers. The examples below are suggestions of how to implement these common visualizations using LML.

4.4.1 Class Diagram

The diagram below shows how to implement the UML Class Diagram using LML classes. Since the Class Diagram has become a standard for software development, it seems a good candidate for inclusion in LML's approach. In this diagram, the LML entities that match the diagram elements include: **Asset** with the *type* "object"; attributes are captured as **Characteristics**; methods are **Actions**; and relationships are **Logical** connections.

UML CLASS DIAGRAM

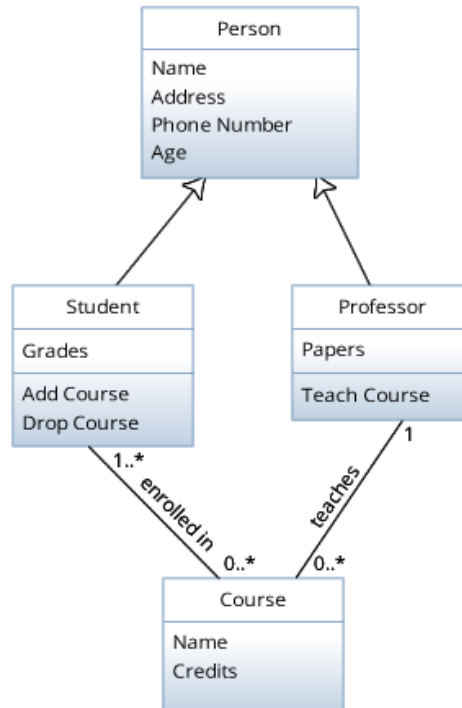


Figure 4-6. LML Encourages Use of the Class Diagram and Provides the Schema Entities to Support Its Creation.

4.4.2 Entity-Relationship Diagram

Another way to model information has been the classic entity-relationship diagram (ERD). An example of this is shown below for the LML schema. The relationships are expressed using the **Logical Connection**. Entities are represented by **Assets**. You can also capture attributes as **Characteristics**.

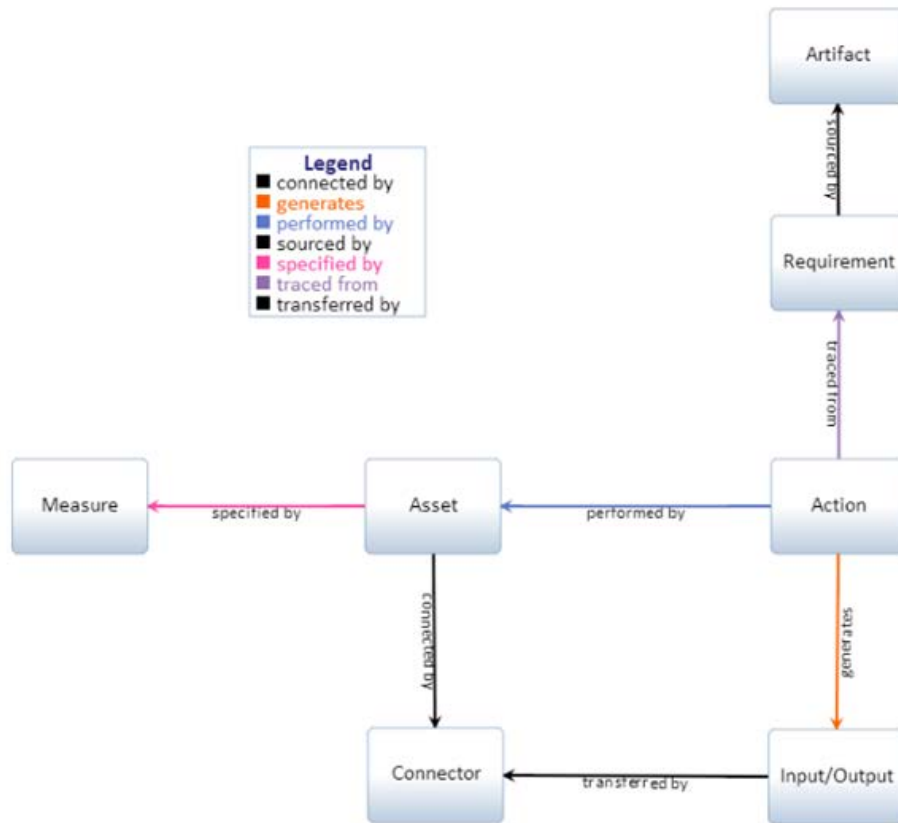


Figure 4-7. Entity-Relationship Diagram Developed Using the Asset Diagram.

4.4.3 Timelines

The **Actions** and **Times** can be displayed using a classic Gantt Chart shows how functional elements execute over time. An example of this is shown below.

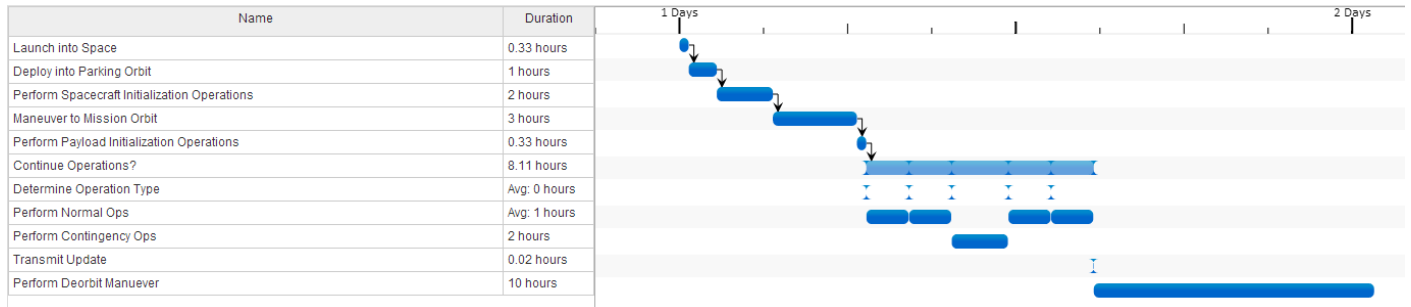


Figure 4-8. Use of Gantt Chart for Displaying Actions and Durations.

Time with **Actions** or **Assets** can be also be visualized in many other ways. One of the most useful is shown below.

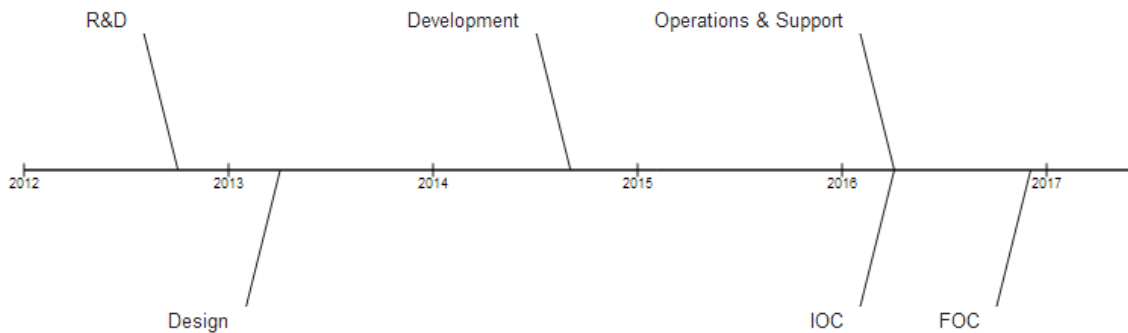


Figure 4-9. Timeline Diagram Showing Actions at Specific Times.

4.4.4 Hierarchy Diagram

A hierarchy chart is used in LML to show decomposition of elements. The figure below shows an example of requirements decomposition. This chart uses the **decomposed by** relationship.

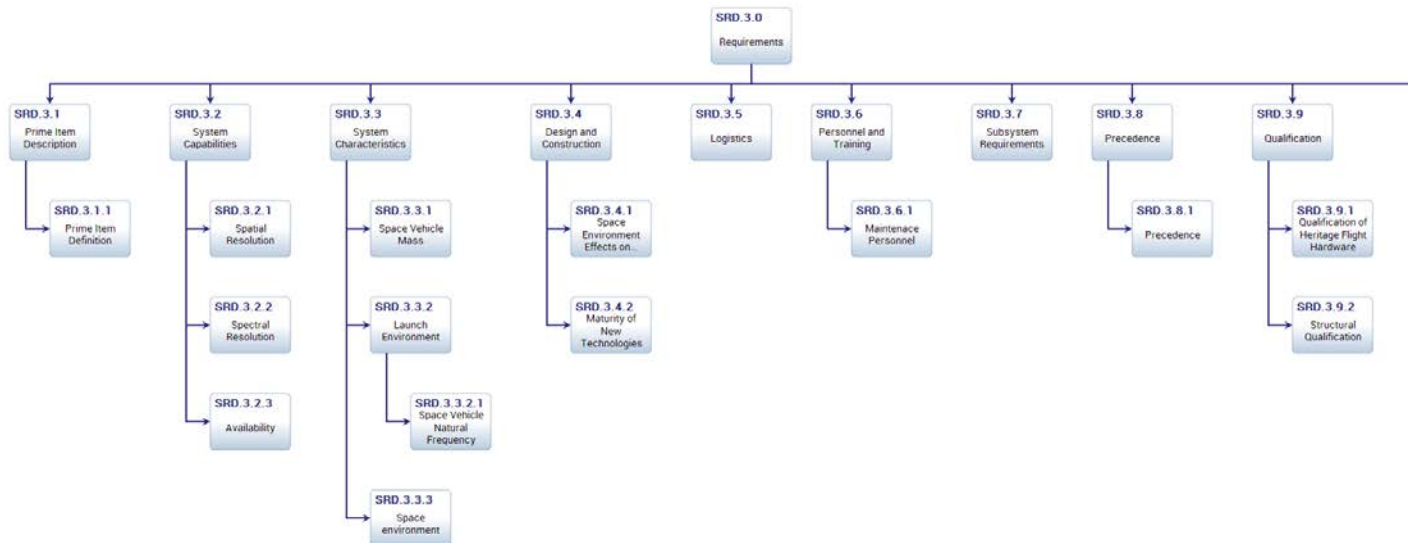


Figure 4-10. A Hierarchy Diagram Is a Good Way to Show Decomposition.

4.4.5 Risk Matrix

A standard DoD risk matrix (shown below) or other form can be used to display **Risk** entity information. Another type of risk analysis uses probabilities to create a fault-tree. A fault tree is often shown as a hierarchy diagram with the probabilities shown for each branch.

	Negligible	Minor	Moderate	Serious	Critical
High	Total: 0 Risks	Total: 0 Risks	Fire Detection Software Development Total: 1 Risks	Total: 0 Risks	Total: 0 Risks
Medium High	Total: 0 Risks	Fire '911' Notification Method Total: 1 Risks	Total: 0 Risks	Payload Focal Plane Technology Total: 1 Risks	Total: 0 Risks
Medium	Total: 0 Risks	Total: 0 Risks	USFS, NOAA, NASA MOA Total: 1 Risks	Total: 0 Risks	Total: 0 Risks
Medium Low	Total: 0 Risks	Total: 0 Risks	Total: 0 Risks	NOAA Ground Station Interface Protocols Total: 1 Risks	Total: 0 Risks
Low	TRL Risk: Payload, TRL Risk: FireSAT OC Analysis Software, TRL Risk: FireSAT OC User Interface Software Total: 3 Risks	Total: 0 Risks	Total: 0 Risks	Total: 0 Risks	Total: 0 Risks

Figure 4-11. Typical Risk Matrix.

4.4.6 State Machine Diagram

The state machine diagram expresses how an **Asset** transitions from one state to another. In the diagram below, the state (or **Characteristic**) transition occurs when the **Action** entity event causes the transition to the other state.

Name	Class	Description
State	Characteristic	Means that it's a state of the system
Initial State	Characteristic	Means that it's the initial state
Final State	Characteristic	Means that it's the final state.

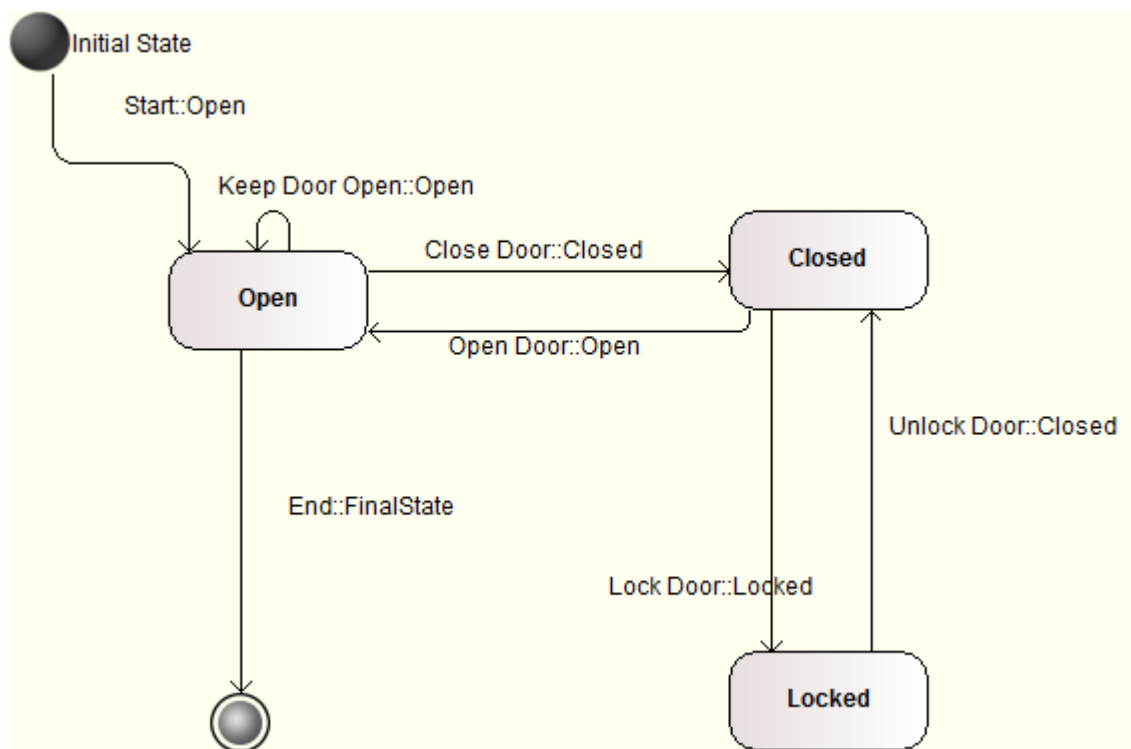


Figure 4-12. The State Machine Diagram Has Proven Useful and LML Supports It.

Appendix A. SysML Mapping to LML

SysML focuses mainly on diagrams, with an underlying ontology embedded in the XML that each diagram represents. Currently (October 2013) a complete ontology is under development. The table below shows the various SysML diagrams and the LML equivalent diagram and associated classes.

Table A-1. SysML Diagram Mapping to LML Diagrams and Ontology

SysML Diagram	LML Diagram	LML Entities
Activity	Action Diagram	Action, Input/Output
Sequence	Sequence	Action, Asset
State Machine	State Machine	Characteristic (State), Action (Event)
Use Case	Asset Diagram	Asset, Connection
Block Definition	Class Diagram, Hierarchy Chart	Input/Output (Data Class), Action (Method), Characteristic (Property)
Internal Block	Asset Diagram	Asset, Connection
Package	Asset Diagram	Asset, Connection
Parametric	Hierarchy, Spider, Radar	Characteristic
Requirement	Hierarchy, Spider	Requirement and related entities

Although the Systems Modeling Language (SysML) does not have an official ontology many tool vendors have created these models from database schemas. The purpose of this appendix is to identify the entities, relationships and attributes necessary for LML to completely visualize the SysML models. The SysML 1.4 standard is available at <http://www.omg.org/spec/SysML/1.4/> (as of 1 December 2015). This appendix will only address the changes to LML required to produce these models.

Note that significant changes between the Action Diagram and the Activity Diagram must occur if developers want to adhere to all the SysML requirements, since Action Diagrams do not contain the large number of constructs used in an Activity Diagram. This specification does not recommend such a large number of constructs as they impede understanding of the diagram. The same content is provided by the ontology.

SPEC Innovations' Innoslate® tool was used as the basis for this extension. Innoslate added one class (Equation) and one subclass to Asset (Port) to visualize the complete set of SysML models. Numerous relationships were added to accommodate the SysML visualizations. The changes to Innoslate's LML schema for SysML are shown in the tables below.

New Classes

Class	Parent	Description
Equation		An Equation entity specifies an equation (mathematical or logical) that can be used to describe a part of the model.
Port	Asset	An interaction point of a block, specifying the input and output flow.

Equation Class

An Equation entity specifies an equation (mathematical or logical) that can be used to describe a part of the model.

Equation Properties

Name	Type	Description
Value	Text	Value represents this Equation's text.

Equation Relations

Name	Classes	Description
decomposed by	Equation	Decomposed by identifies the children of this entity.
decomposes	Equation	Decomposes identifies the parent of this entity.
equation for	Cost	Equation for identifies the entity that this Equation represents.
equation for	Time	Equation for identifies the entity that this Equation represents.
equation for	Characteristic	Equation for identifies the entity that this Equation represents.
equation for	Statement	Equation for identifies the entity that this Equation represents.
equation for	Decision	Equation for identifies the entity that this Equation represents.
equation for	Action	Equation for identifies the entity that this Equation represents.
equation for	Risk	Equation for identifies the entity that this Equation represents.
equation for	Location	Equation for identifies the entity that this Equation represents.
equation for	Asset	Equation for identifies the entity that this Equation represents.
equation for	Artifact	Equation for identifies the entity that this Equation represents.
equation for	Connection	Equation for identifies the entity that this Equation represents.
equation for	Input/Output	Equation for identifies the entity that this Equation represents.
has variable	Characteristic	Has variable identifies the Characteristic that is represented in this Equation.
related to	Equation	Related to identifies the entity that ties in a peer-to-peer way with this entity.
relates	Equation	Relates identifies the peer-to-peer entity that is tied to this entity.

Port Class

An interaction point of a block, specifying the input and output flow.

Port Properties

Name	Type	Description
Direction	Enumeration	Direction represents the flow of data on this port.

Action Relations

Name	Classes	Description
depends on	Action	Depends on identifies the Action that this Action has a dependency on.
equation of	Equation	Equation of identifies the Equation that represents this entity.
extend	Action	Extend identifies the Action (use case) that is added to this Action (use case).
extended by	Action	Extended by identifies the Action (use case) that is added from this Action (use case).
fetches	Characteristic	Fetches identifies the State Characteristic that this Action receives.
has dependent	Action	Has Dependent identifies the Action that depends on this Action.
include	Action	Include identifies the Action (use case) that is added to this Action (use case).
included by	Action	Included by identifies the Action (use case) that is added from this Action (use case).
pushed by	Characteristic	Pushed by identifies the State Characteristic that this Action is generated from.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Artifact Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Asset Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
extend	Asset	Extend identifies the Action (use case) that is added to this Action (use case).
extended by	Asset	Extended by identifies the Action (use case) that is added from this Action (use case).
instantiated by	Asset	Instantiated by identifies another entity that is an instance of this entity.
instantiates	Asset	Instantiates identifies another entity that has this entity as an instance.

Name	Classes	Description
represented in	Asset	Represented in identifies the Asset who's diagrams include this Asset.
represents	Asset	Represents identifies the Asset that is included in this Asset's diagrams.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Characteristic Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
fetches by	Action	Fetches by identifies the Action that this State Characteristic is received by.
generates	Input/Output	Generates identifies the Input/Output or Action that this Action or Characteristic transforms.
generates	Action	Generates identifies the Input/Output or Action that this Action or Characteristic transforms.
instantiated by	Characteristic	Instantiated by identifies another entity that is an instance of this entity.
instantiates	Characteristic	Instantiates identifies another entity that has this entity as an instance.
pushes	Action	Pushes identifies the Action that this State Characteristic generates.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
variable of	Equation	Variable of identifies the Equation that this Characteristic is represented in.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Conduit Relations

Name	Classes	Description
instantiated by	Conduit	Instantiated by identifies another entity that is an instance of this entity.
instantiates	Conduit	Instantiates identifies another entity that has this entity as an instance.

Connection Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Cost Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Decision Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.

Input/Output Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
instantiated by	Input/Output	Instantiated by identifies another entity that is an instance of this entity.
instantiates	Input/Output	Instantiates identifies another entity that has this entity as an instance.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Location Relations

Name	Classes	Description
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Requirement Relations

Name	Classes	Description
copied by	Requirement	Copied by identifies the Requirement that is a clone of this Requirement.
copies	Requirement	Copies identifies the Requirement that this Requirement clones.
derived by	Requirement	Derived by identifies the Requirement that is developed from this Requirement.
derives	Requirement	Derives identifies the Requirement that this Requirement develop from.
refined by	Requirement	Refined by identifies the Requirement that clarifies this Requirement.
refines	Requirement	Refines identifies the Requirement that this Requirement clarifies.
satisfied by	Cost	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Time	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Action	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Artifact	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Asset	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Location	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Input/Output	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Characteristic	Satisfied by identifies the entity that fulfills this Requirement.
satisfied by	Connection	Satisfied by identifies the entity that fulfills this Requirement.
verified by	Input/Output	Verified by identifies the entity that supports this Requirement.
verified by	Characteristic	Verified by identifies the entity that supports this Requirement.
verified by	Asset	Verified by identifies the entity that supports this Requirement.
verified by	Artifact	Verified by identifies the entity that supports this Requirement.
verified by	Time	Verified by identifies the entity that supports this Requirement.
verified by	Action	Verified by identifies the entity that supports this Requirement.
verified by	Requirement	Verified by identifies the entity that supports this Requirement.
verified by	Cost	Verified by identifies the entity that supports this Requirement.
verified by	Connection	Verified by identifies the entity that supports this Requirement.
verified by	Location	Verified by identifies the entity that supports this Requirement.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Risk Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.

Statement Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.

Time Relations

Name	Classes	Description
equation of	Equation	Equation of identifies the Equation that represents this entity.
satisfies	Requirement	Satisfies identifies the Requirement that is fulfilled by this entity.
verifies	Requirement	Verifies identifies the Requirement that is supported by this entity.

Appendix B. DoDAF MetaModel 2.0 (DM2) Mapping to LML

The Department of Defense has developed a schema called the DoDAF (DoD Architecture Framework) MetaModel 2.0 (DM2). The Conceptual Data Model is shown below. The physical data model contains over 500 entries. As can be seen this is a specialized model that focuses mainly on the DoD nomenclature and may be less useful in other domains. For example, since the DoD has developed their acquisition process around the concept of “Capability” that becomes a critical item in the top level of this schema, thus driving additional relationships. In LML we identified that capability could be a type of **Action**, **Asset**, **Characteristic** or even a **Statement**. However, LML does not preclude the user or tool vendor from adding “Capability” as an entity class. Schema extensions are actually encouraged for different domains. As such extensions are made and standardized; the LML Steering Committee will consider adding them as extensions to LML.

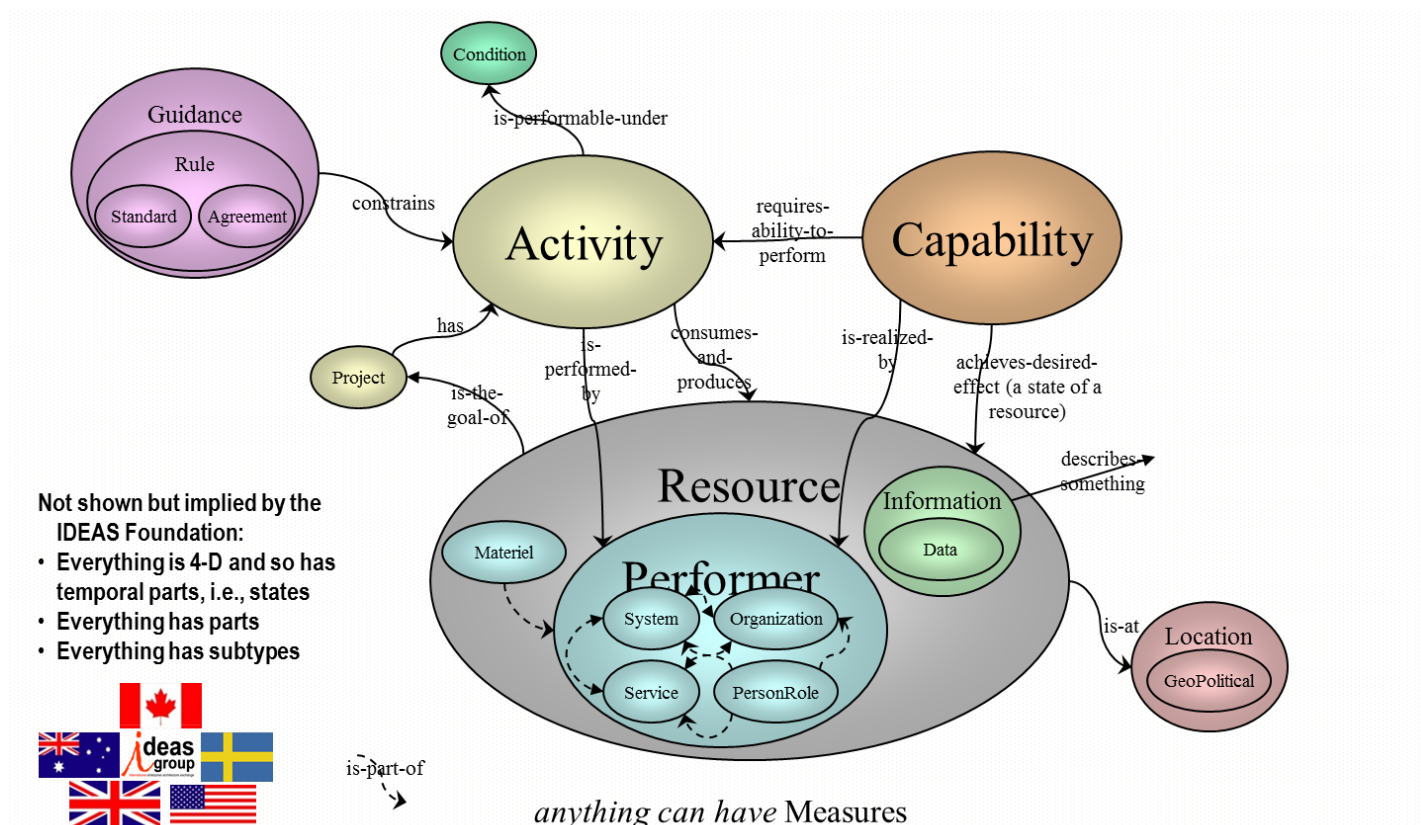


Figure B-1. DM2 Conceptual Data Model.

For a quick guide from the DM2 schema to LML, please see the table below.

Table B-1. DM2 Conceptual Data Model Mapping to LML

DM2 Schema Element (Conceptual)	LML Equivalent
Activity	Action
Capability	Action with “Capability” label
Condition	Characteristic with “Condition” label
Information/Data	Input/Output
Desired Effect	Statement with “Desired Effect” label
Guidance	Statement with “Guidance” label
Measure	Measure
Measure Type	Measure labels
Location	Location
Project	Action with “Project” label
Resource	Asset with labels for “Materiel,” “Organization,” etc.
Skill	Characteristic with label “Skill”
Vision	Statement with label “Vision”