



Requirements Writing in SysML

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This document proposes structuring and styling rules that help writing requirements using the SysML language as well as specific MagicDraw capabilities that support this process.

Prerequisites: basic MagicDraw knowledge; basic knowledge of the SysML language requirements part¹.

The biggest issue users have when they start writing requirements using the *SysML* language is that there is little information on how to properly layout the requirement diagrams, how to relate them to other *UML* or *SysML* diagrams, how to structure the requirements project into layers, what the granularity of the requirements should be, how evolution of the requirements should be handled, etc. In other words, there is quite a lot of information describing language concepts themselves, not so many practical experiences describing how to use that language in the real-world.

In this guide, we share *No Magic, Inc.* experience using the *SysML* language for developing *MagicDraw* product itself. We hope that this document can lead to a two-way sharing of experience and ideas – if you as a reader have suggestions or questions, you are very welcome for a discussion.

Requirement Layers

Every product (tool, plugin, or framework) should have a single MagicDraw requirements project which should hold requirements for the current *state* of the product. The recommended name for the requirements project is “<Tool | Plugin name | Framework > Requirements”, e.g. “Cameo Infrastructure Requirements” or “MagicDraw Requirements”.

The requirements within a project should be expressed in the “shall” form stating how the system should work instead of specifying what has to be changed from the current state.

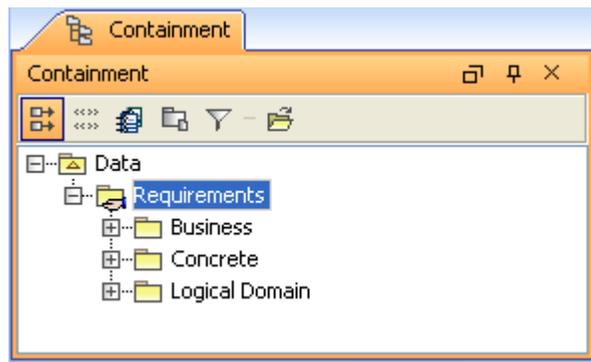


FIGURE 1 Package structure of a requirements project.

A requirements project should have a single root package called *Requirements* which should contain all the requirements under it (directly or indirectly). It should be **shared** so that the development and QA could use the requirements for their needs.

The *Requirements* package should have three packages under it (see FIGURE 1):

¹ Recommended books to get acquainted with the requirements part of the SysML language:
- Tim Weilkiens. Systems Engineering with SysML/UML: Modeling, Analysis, Design (The MK/OMG Press)
- Sanford Friedenthal, Alan Moore, Rick Steiner. A Practical Guide to SysML: The Systems Modeling Language (The MK/OMG Press)

- *Logical Domain*. This package should contain domain models expressed in *UML* class diagrams. More information on this is provided in the following chapters of this document.
- *Business*. This package should contain high-level (business) requirements. Requirements in this package should be independent of the requirements specified elsewhere in this project.
- *Concrete*. This package should contain requirements that implement or satisfy the business requirements. Requirements in this package should only depend on the requirements specified in the *Business* package via the «*derive*» relationships. For example if the business requirement is 'The system shall track changes in projects', then its counterpart in concrete requirements could be 'The system shall support element-level versioning'.

FIGURE 2 summarizes what has been described so far. It shows the dependencies between the requirements in top-level requirement packages expressed as «*derive*» relationships.

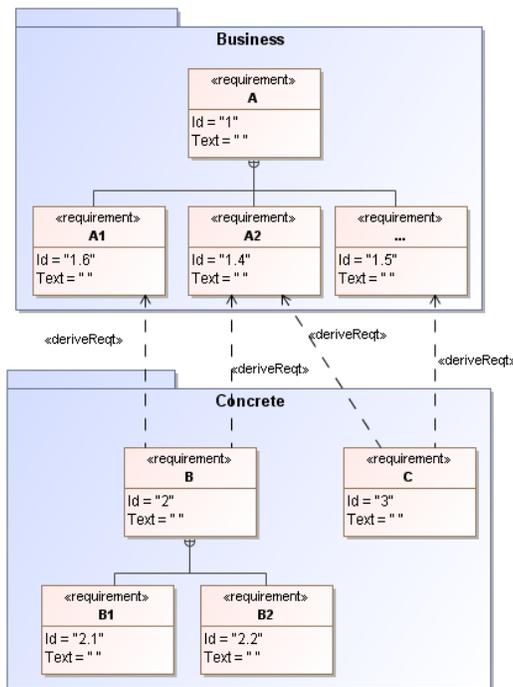


FIGURE 2 Dependencies between requirements in top-level packages.

Contents of the Business Requirements Layer

The *Business* requirements package should have a single non-derived requirement root element (we will further refer to this element as to *root requirement* in this document). There can be other root requirements but they can only be derived directly or indirectly from the root requirement. In order to emphasize that there is only a single true root element, other root elements should be moved into packages which represent logical units of a system. Non-derived and derived **root** elements should be owned by the packages. Other requirements should be owned by requirements. In other words, the requirement should either be a root requirement, or belong to the root requirement directly or indirectly, or be derived from the requirements that belong to the root requirement directly or indirectly.

The root requirement should be named the same as the framework/tool/plugin is named (without version), e.g. *Cameo Infrastructure*.

There should be a **single diagram** directly under the *Business* package or owned by the *root requirement*. It should be the starting point for reading framework/tool/plugin requirements (e.g. its name could be *High-Level Requirements*). This diagram should have a symbol representing the root requirement and (possibly) its directly owned requirements.

The sample structure of the *Business* package is shown in FIGURE 3. There is a root requirement under this package and a single diagram graphically representing it. There is also a bunch of packages which contain requirements derived directly or indirectly from the root requirement.

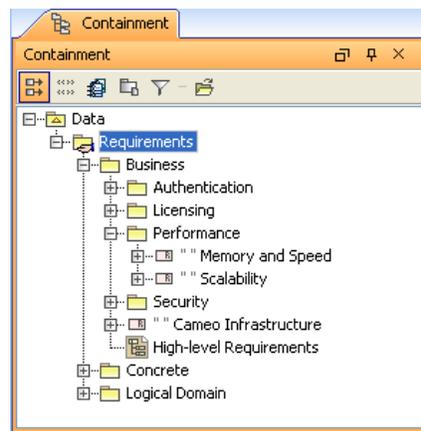


FIGURE 3 Structure of the Business package.

Contents of the Concrete Requirements Layer

As stated earlier, requirements in the *Concrete* package should have requirements that “implement” or satisfy requirements in the *Business* layer. Requirements in this package should be derived from the requirements in the *Business* package. Generally, the same rules from the *Business package* apply here except that there is no root requirement. All the requirements here are derived and should be owned by packages which on their own should be owned by other packages or the *Concrete* package. As for the contents of the packages under the *Concrete* package, they should contain both functional and *GUI* requirements.

Sample structure for the *Concrete* package is shown in FIGURE 4.

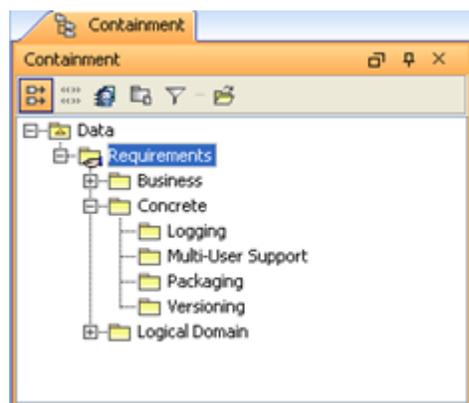


FIGURE 4 Structure of the Concrete package.

Domain Models

Domain models should be owned by the *Logical Domain* package (see FIGURE 5). Each package should be structured on its own. Package structure should be created in accordance to the logical parts of a modeled system.

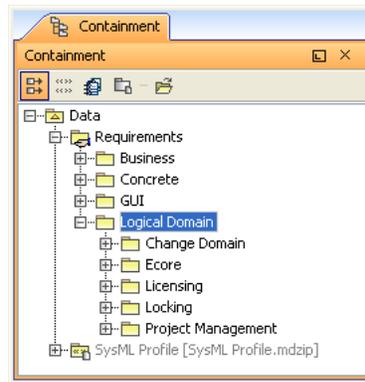


FIGURE 5 The Logical Domain Package.

Domain models are be modeled using class diagrams. Sometimes state machine, activity or sequence diagrams are also used in addition to class diagrams. Class diagrams should be owned by the packages residing in the *Logical Domain* package. Sometimes it is needed to describe the overall domain model of a particular feature in several aspects. In such a case each aspect shall be modeled in a separate class diagram. The diagrams describing separate aspects should still be owned by the same package that holds classes describing the feature.

Requirement Diagram Ownership

Requirement diagrams should be owned by the requirements they represent. In some cases requirement diagrams can be placed next to the represented requirements. This approach is less recommended as the diagram in this case is not kept together with the requirement and all refactoring-related actions should be performed twice on both the requirement and the diagram (e.g. moving a requirement to new location will require moving the diagram to another location too). This may lead to situations where diagrams are scattered over the model in different places than the represented requirements. This would make reading the requirements model quite a hard task.

In FIGURE 6, the root requirement is named *Cameo Infrastructure*. There is a diagram *High-Level Requirements* that represents this requirement and is owned by the *Business* package. There is also a diagram called *Scalability Requirements*, which is owned by the *Scalability* requirement and it graphically represents the *Scalability*, *Storage*, and *Distribution* requirements and their subrequirements.

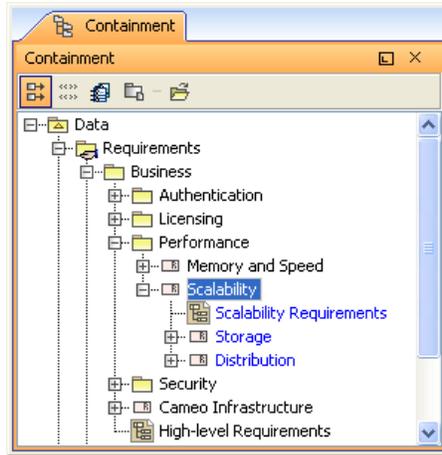


FIGURE 6 Ownership of Requirement Diagrams.

Element Layout in Requirement Diagrams

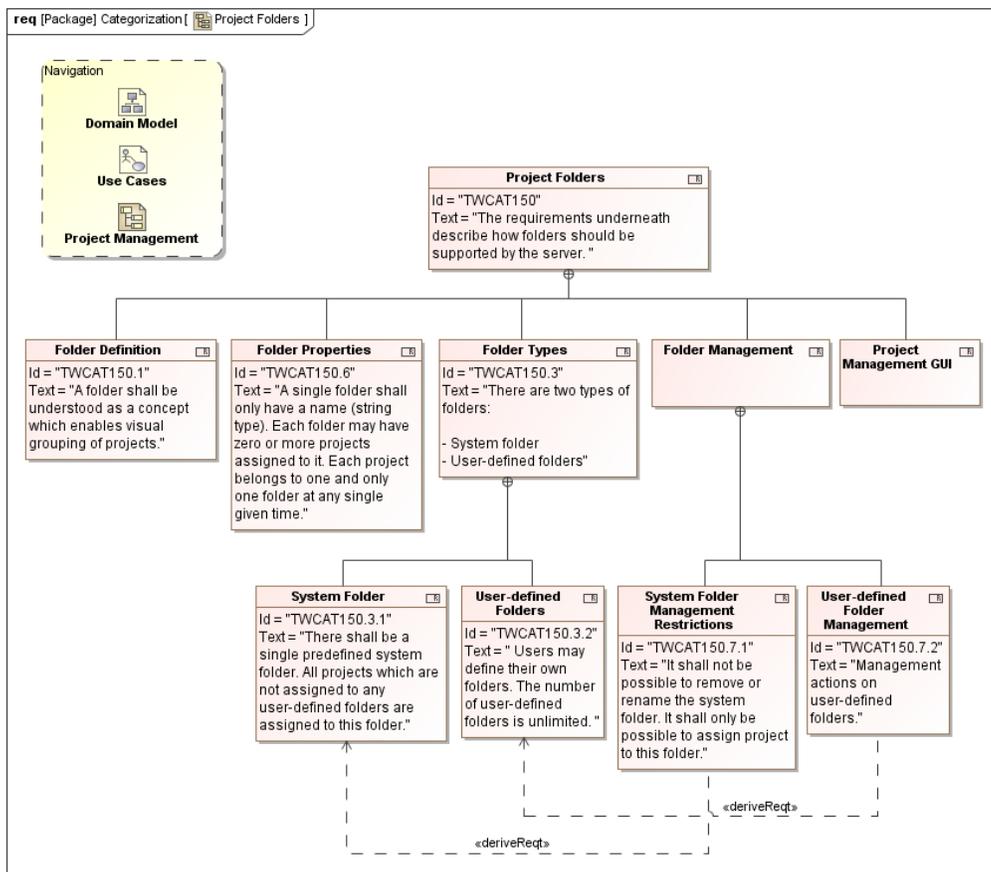


FIGURE 7 Requirement diagram areas.

There should be mainly two areas in each requirement diagram (see FIGURE 7 for an example):

- *Navigation area.* There should be an area in the diagram for putting links to/from related diagrams (e.g. there is a yellow rectangle shape at the top left corner in the diagram)

shown in FIGURE 7 holding hyperlinks to domain models and related requirement diagrams). If the requirement diagram refines a requirement from another requirement diagram, the *Navigation* area should have a hyperlink to that diagram.

- *Requirements modeling area.* There should be a **single** root node and a certain level of its owned requirements in a single requirement diagram. One nesting level is recommended. However, if the number of requirements in each nesting level is small (e.g. 1-4 requirements), there can be more nesting levels in a single diagrams. Requirements that have more than 5 owned requirements should be refined in separate diagrams. Having more than **one** root node would possibly mean that the *navigation* area would contain backlinks to different contexts which could possibly confuse the reader if he/she wanted to navigate to objects from a single context. Requirements from other contexts, e.g. derivation targets, should be of a different color (for example the color could be *yellow* as shown in FIGURE 7). This is required to distinguish the requirements in the current context from the requirements in other contexts.

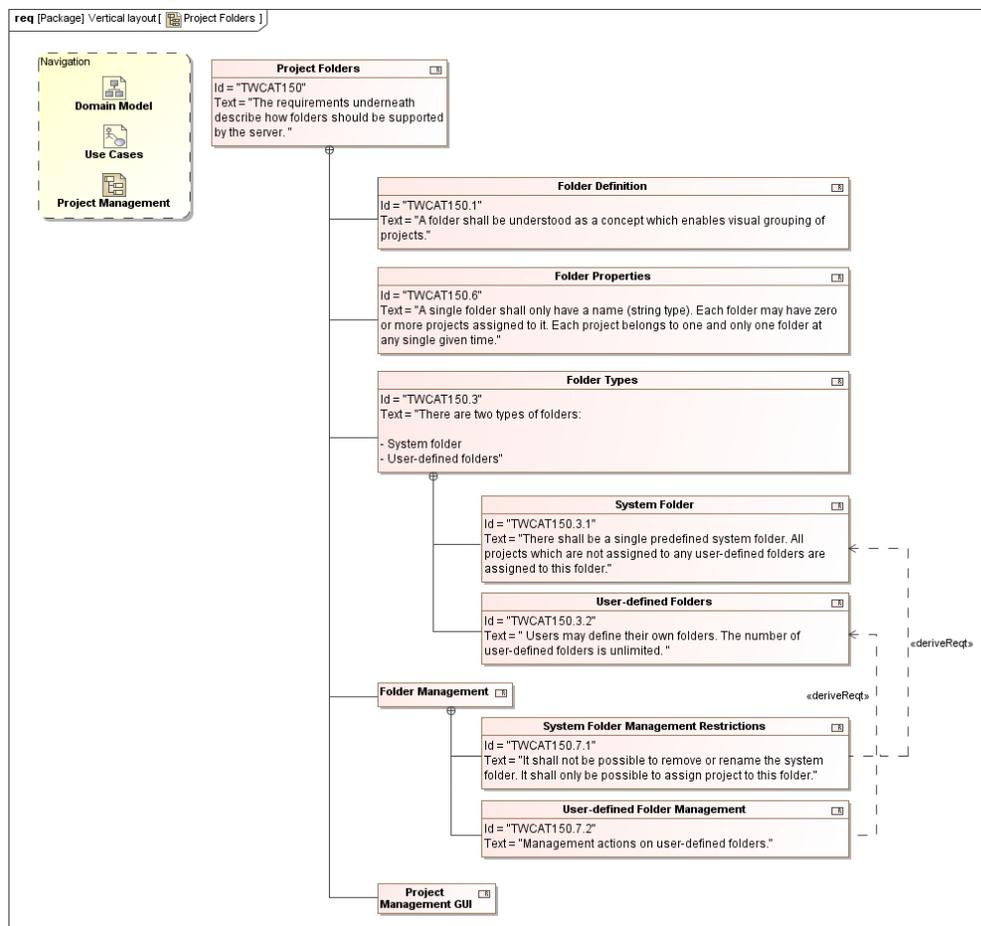


FIGURE 8 Vertical requirement layout.

Requirements in the *Requirement modeling* area can be laid-out in three different ways:

- *Horizontally.* In this layout, requirements of the same nesting level are laid-out horizontally. Nested requirements are positioned below the owning requirement by aligning the center of the whole row of requirements to the center of the owning requirement. This layout type is handy when requirement texts are not large (and they

should not be large; if they are – they **should be** decomposed into several requirements). Requirements in this layout are read in the *left-to-right, depth first* order. Horizontal layout **is the recommended** layout. A sample of horizontal requirement layout is depicted in FIGURE 7.

- *Vertically.* In this layout, requirements of the same nesting level are laid-out vertically. Nested requirements are positioned below the owning requirement by shifting the whole column of requirements to the right relatively to the owning requirement. This layout type is handy if there is a list of requirements whose texts take a considerable amount of space. A sample of vertical alignment is depicted in FIGURE 8.
- *Horizontally and vertically in a single diagram (mixed layout).* Sometimes it is useful to mix horizontal and vertical layouts in a single diagram, e.g. for saving diagram space. FIGURE 9 shows a sample requirement diagram where requirements *Reusable Dialogs*, *General Requirements for a Dialog Window*, and *Open Dialogs Only When Connected to Server* are laid-out horizontally, where others are laid-out vertically to save space (this is much more readable and understandable than organizing the requirements horizontally in this particular case).

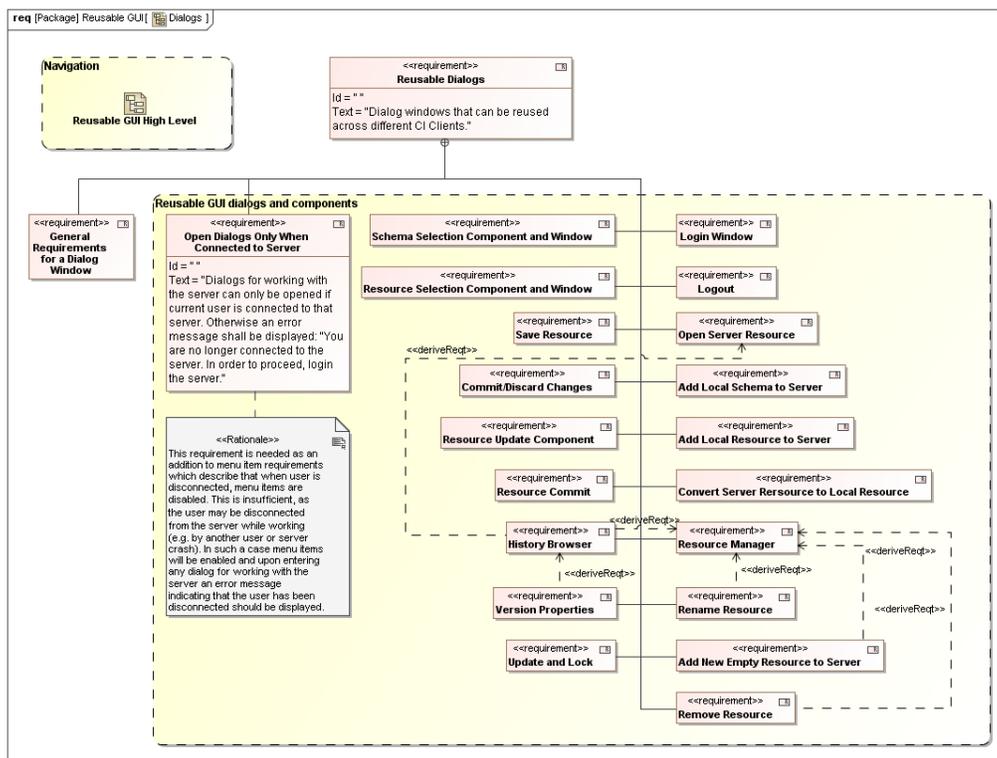


FIGURE 9 Mixed requirement layout.

Note

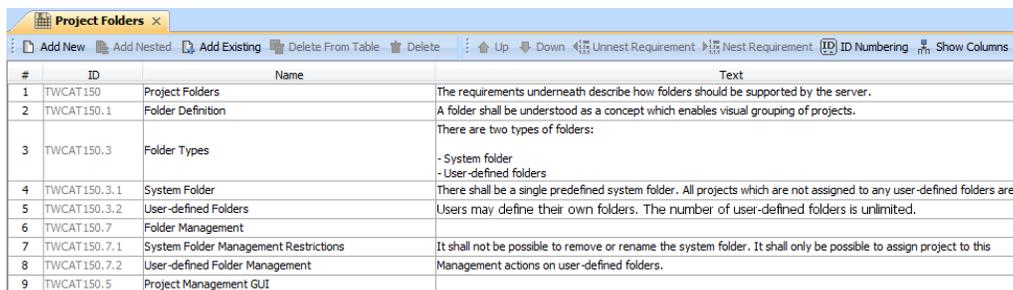
This section only describes three layouts that are most common, however depending on the situation you can layout requirements differently, e.g. when you have only derived requirements in a single diagram you may want to use something different.

Requirement Hyperlinking

Requirements should have hyperlinks to the requirement diagrams in the following cases:

- If the requirement is refined with another diagram, then it should have a hyperlink to the refining diagram;
- If the requirement *B* is derived from the requirement *A* then both *A* and *B* should have hyperlinks to the diagrams in which they are described if these diagrams are different. The diagram where *A* is described should have a symbol representing *B* and the derivation path to *B*. The diagram where *B* is described should have a symbol representing *A* and the derivation path to *A*.

Using SysML Requirements Tables



The screenshot shows a SysML Requirements Table titled "Project Folders". The table has four columns: #, ID, Name, and Text. It contains 9 rows of requirements related to project folder management.

#	ID	Name	Text
1	TWCAT150	Project Folders	The requirements underneath describe how folders should be supported by the server.
2	TWCAT150.1	Folder Definition	A folder shall be understood as a concept which enables visual grouping of projects.
3	TWCAT150.3	Folder Types	There are two types of folders: - System folder - User-defined folders
4	TWCAT150.3.1	System Folder	There shall be a single predefined system folder. All projects which are not assigned to any user-defined folders are
5	TWCAT150.3.2	User-defined Folders	Users may define their own folders. The number of user-defined folders is unlimited.
6	TWCAT150.7	Folder Management	
7	TWCAT150.7.1	System Folder Management Restrictions	It shall not be possible to remove or rename the system folder. It shall only be possible to assign project to this
8	TWCAT150.7.2	User-defined Folder Management	Management actions on user-defined folders.
9	TWCAT150.5	Project Management GUI	

FIGURE 10 Requirements table.

In some cases, requirements tables (see FIGURE 10) can be used instead of ordinary requirements diagram. This diagram is mostly useful in situations where there is a single requirement which has one nesting level of requirements under it. It is worth noting that the table is not capable of showing derivations and other relationships, thus the usage of this table is limited currently. In cases where relationships and related elements need to be displayed, the *Generic Table* can be used. This diagram is not specifically devoted for requirements, but requirements can be managed in it too.

Modeling GUI Requirements

It is recommended to use a single template for modeling all *GUI* requirements. An example of such a template is described in this subsection.

A diagram representing requirements for a single window should at least satisfy the following requirements:

- It should have a single root requirement that groups requirements for the whole window;
- Requirements directly owned by the root requirement should describe:
 - How the window is opened (by clicking on some button, automatically, etc.);
 - Title of the window;
 - Any informational messages or descriptive texts the window has, e.g. texts that describe what the window does;
 - Data management components. Usually requirements for data tables or data input/editing fields are placed under this requirement;

- Data management buttons. Buttons that perform actions on entered or selected data are placed under this requirement.
- In *MagicDraw*, it is strongly recommended to use the *User Interface Modeling Diagram* for sketching the *GUI*. If this diagram is used, a sketch of the dialog should be created in a separate diagram to which a hyperlink should be created from the root requirement. Alternatively the *Diagram Overview* shape could be used to display contents of the *GUI* in the requirements diagram (see FIGURE 11 for an example). If the *User Interface Modeling Diagram* cannot be used, there should be a sketch of the dialog placed in the same diagram and it should be attached to the root requirement.

A sample requirements diagram of the *Open Server Project* window is shown in FIGURE 11.

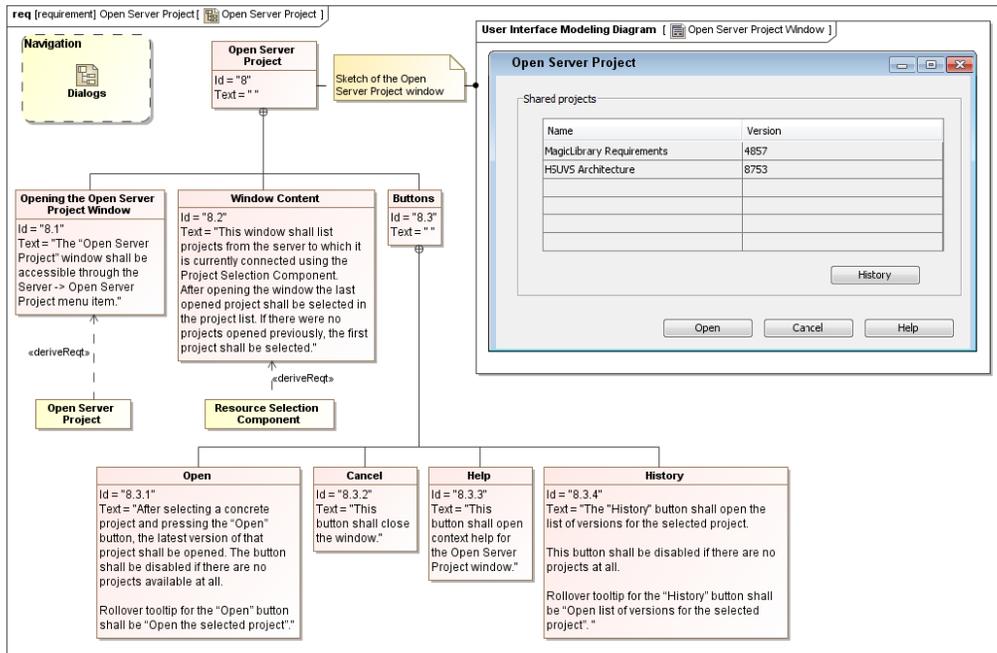


FIGURE 11 GUI requirements for a single window.

Requirement Decomposition

When writing requirements in *SysML* a question when to decompose a requirement into other requirements arises quite often. The rules here are as follows:

- if some part of the requirement is going to be used somewhere else, e.g. some other requirement derives from it, or it is a subject to decomposition itself, then the requirement should be decomposed into smaller requirements
- if the requirement has information from different (sub)topics, it should also be decomposed into subrequirements
- if parts of the requirement are not used by any other requirement and the requirement holds information that naturally describes the same topic or thing, but the text of the requirement becomes too big (e.g. 8-10 sentences), it should still be decomposed into several requirements for better readability

Containment vs. Derivation vs. Trace

It is important to distinguish when to use derivation and when containment.

If a requirement contains or owns other requirements, it serves as a grouping requirement and does not enforce any true requirements itself. Its text field usually describes the group of requirements in general (a brief text describing what are all owned requirements for), but does not really imply any requirements that should be directly implemented. So, if it is needed to only structure the requirements, the containment should be used.

If there is a relationship of the *supplier-client*, *producer-consumer*, *reason-consequence*, *interface-implementation*, *need-satisfaction*, *abstract-concrete* type between requirements, then the «*derive*» relationship should be used between them, not containment. Derivation targets should be requirements playing roles specified on the left hand side in the aforementioned relationship types (*client*, *consumer*, *reason*, etc.), derivation sources should be requirements playing roles specified on the right hand side (*supplier*, *producer*, *consequence*, etc.). In essence, the following can be used to understand if the derivation should be modeled or not: if we have a requirement A related with requirements B, C, and D such that after changing the requirement A, requirements B, C, and D should be reviewed, then B, C, and D should be derived from A.

The «*trace*» relationship only signifies that the requirement is somehow related to *any other* the model element. This relationship does not even specify the direction of the relationship (even if there is an arrow, there is no direction, the arrow has no meaning). An important aspect here is that the «*trace*» relationship is only modeled between the requirement and other model elements (non-SysML-requirements).

«*satisfy*» relationship

The «*satisfy*» relationship describes how a design or implementation model satisfies one or more requirements. A system modeler specifies the system design elements that are intended to satisfy the requirement, e.g. architecture classes satisfying the requirements. This relationship **should not** be used between requirements.

About the Author



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Andrius is the MagicDraw Product Manager and MagicDraw Analyst Team Manager with more than ten years of experience in software development. As a Product Manager, he is responsible for setting directions for the product, its roadmap and vision, and selecting features for each new version of MagicDraw. His responsibilities also include understanding the market and the competitive environment. As the Analyst Team Manager, Andrius is responsible for the MagicDraw R&D team, ensuring requirements quality and completeness, requirements gathering and specification processes.

Andrius joined No Magic as a System Analyst and trainer. He was responsible for teamwork-related features such as branching and the Merge plugin. This work included work from the initial product ideas to final product delivery, various diagramming improvements, and research related to supporting new standards. Andrius has conducted numerous training in Europe. Andrius is an OMG Certified UML Professional.

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