

Assurance Case Guide

Part 1. Argument Structure

25.04.2025

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1 Introduction

This document describes what an assurance case is and explains the argument notations used in PREMIS. An example assurance case is presented and the steps of the reasoning are discussed.

There are several publications which define assurance cases, such as the ISO 15026 standard, GSN Community Standard and OMG SACM. Argevide PREMIS implements a general metamodel of the argument compliant with OMG SACM, which allows the use of specific argument notations like GSN. In this document we present the general concept of an argument model and refer to specific notations where necessary.

1.1 The concept of an assurance case

An **assurance case** is a structured, compelling argument, supported by evidence, justifying that a system has some postulated properties in a specific context and environment.

Goals specify properties of the system that are to be demonstrated by the assurance case. They have to be specified to start development of an argument.

The goals are specified in the context of the **system** and its **environment**. The system is the subject of the assurance goals. It can be a simple device, a complex system or a set of integrated systems, an organization or a process. The system operates in the environment which includes operational physical objects, regulations and any information external to the system. The description of the system and the environment should be sufficiently detailed to allow for unambiguous interpretation of the goals, the argument and evidence.

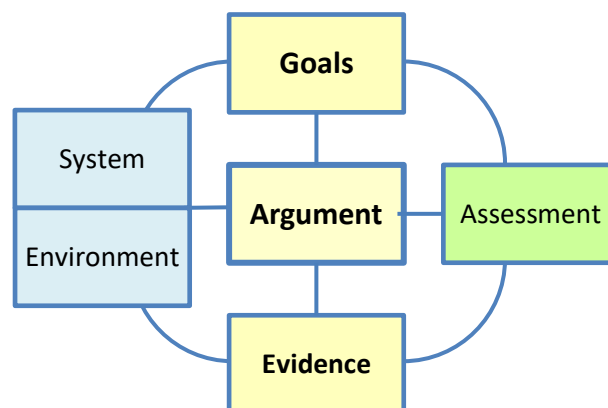


Figure 1. General assurance case model

The **Argument** contains an explicit and verifiable reasoning supported by evidence which demonstrates that the specified goals are achieved. It is the core element of an assurance case.

The argument is to be supported by **evidence**. Evidence is a verifiable and auditable information used to support the argument. Evidence can be presented in any technical form (documents, data, photos, video, measurement reports). To be valid, the evidence needs to be up to date and consistent with the actual state of the system.

The last component of an assurance case is the **assessment**. The assessment is produced as a result of a systematic review of the argument and evidence. It gives information whether the argument and evidence fully support the goals defined for a given assurance case. A positive assessment result is the basis for the assurance case approval.

Assurance case report is a static document which presents assurance goals, the argument structure and references to evidence. It's usually created for approved versions of an assurance case.

The assurance case, unlike to the report, is a living object and it should evolve during the system lifecycle to represent the current state of the required system properties.

2 The steps of the argument

The objective of the argument is to explicitly present the reasoning how the goal is supported by the evidence.

A simplified argument structure is presented in Figure 2. The argument starts with the goal “Device is adequately safe”. The goal should be defined in the context of a specific device and its context of use, but for simplicity we will skip this for now.

Goals and any statements in the argument are defined as **claims**. A claim is a true-false statement, a predicate. The sentence “Device is adequately safe” is a true-false statement as it can be either true or false. Such a claim would require a precise definition of what the system is and what level of safety is adequate, but we won't focus on that issue at the moment. Each claim should be defined in an unambiguous way. We will describe how we define claims in the next section.

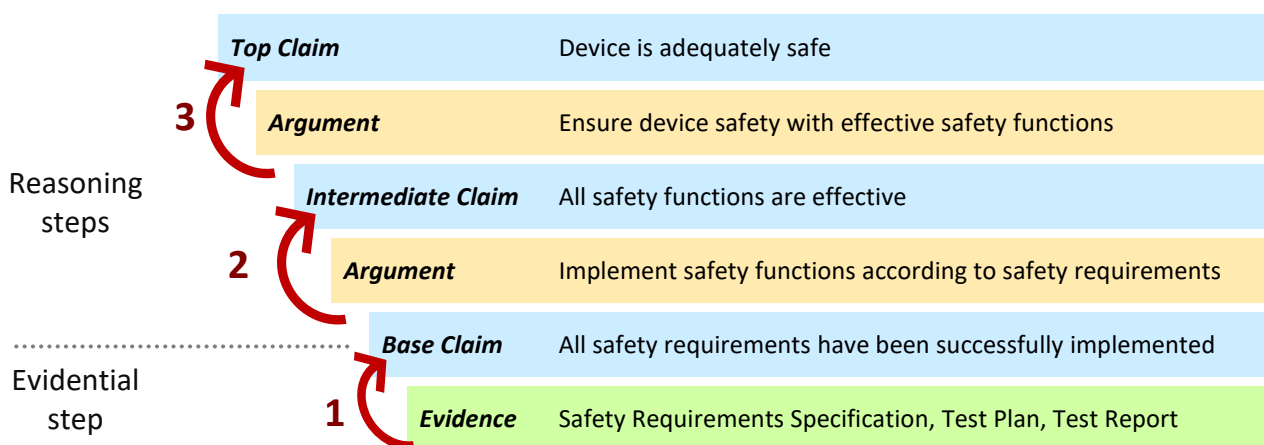


Figure 2. General argument structure and the flow of reasoning

The argument presents a line of reasoning from the evidence presented at the bottom of the diagram to the claim presented on the top. The reasoning is divided into steps and we distinguish two types of **argument steps**: reasoning steps and evidential steps.

The lowest level of the argument consists of **evidential steps**. The step number 1 is an example of an evidential step. The objective of this step is to establish **base claims** backed directly by evidence. In our example we use Safety Requirements Specification, Test Plan and Test Report as the evidence. The step is **valid** when, on the basis of the evidence, we can conclude that the base claim is correct. The base claim should be defined in a way that is supported directly by the evidence. No reasoning should take place in the evidential step of the argument. The evidential step should be simple and straightforward.

Steps 2 and 3 are **reasoning steps** which describe the reasoning how a given claim can be inferred from its supporting claims. The supporting claims are presented in the lower part of the step. They form premises for a given reasoning step. The claim on the top is the conclusion. The relation between the premises and the conclusion is described by an argumentation strategy which defines the line of reasoning.

We usually develop assurance cases top-down and the process is not completed until we define all the evidence to support the argument. When you analyse the reasoning you go bottom-up. You start with evidence and draw conclusions going up step by step. The final conclusion should be the top claim of the argument.

3 Argument presentation – argument diagrams and argument tree

There are a few ways how an argument can be presented an argument, graphical, textual, tabular. PREMIS implements two ways of presentation:

- Graphical argument representation – **diagrams** such as defined in Goal Structuring Notation (GSN) Community Standard.
- Hierarchical textual presentation in the form of an **argument tree**. It's a convenient form for quick argument development and modification.

The argument tree view uses indentation to represent the level of the argument hierarchy. This representation is intuitive and makes actions such as adding or moving elements quick and easy, as you do not have to rearrange the layout of the diagram.

On the other hand, a graphical representation is better for presenting and discussing the assurance case. The two ways of argument presentation are equivalent. Each argument tree argument can be presented in a diagram, and each diagram can be presented as an argument tree.

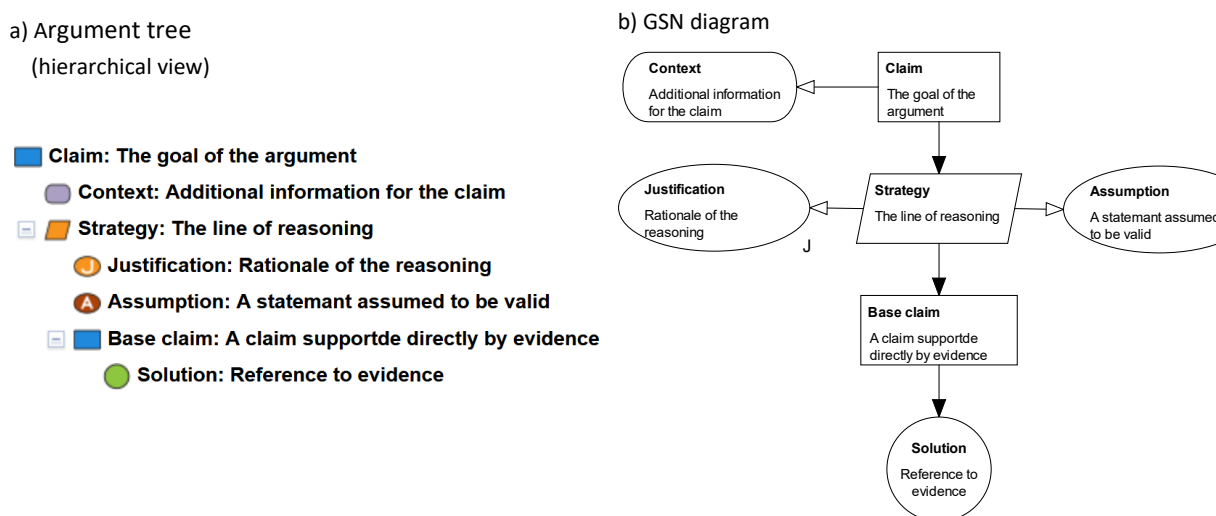


Figure 3. Argument tree view (left) and a corresponding GSN diagram (right)

PREMIS implements both ways of argument presentation.

To learn more about GSN you can refer to “Goal Structuring Notation Community Standard” version 3 published in May 2021 (<https://scsc.uk/gsn>) by Assurance Case Working Group (ACWG) at Safety-Critical Systems Club (SCSC).

GSN notation is also used in the latest edition of ISO 15026-2 standards “Systems and software assurance – Assurance case” released in year 2022.

4 The reasoning step

We will discuss the argument going top-down. That is the way we usually develop assurance cases.

The top fragment of the argument is presented in Figure 4. We add identifiers to all argument elements to make referring to them easier. The argument starts with the top claim C1 “Device is adequately safe”.

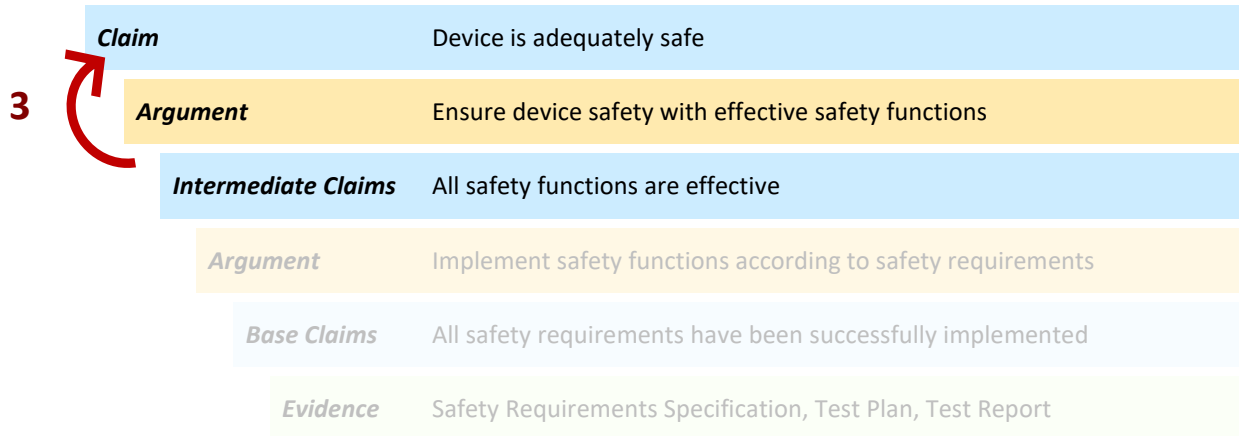


Figure 4. The top-level reasoning step of the argument for device safety

In this reasoning step we argue that the device is adequately safe (the top claim C1) when all safety functions are effective (claim C2). The reasoning is defined by two elements: an argumentation strategy and a rationale.

A **strategy** specifies the inference rule used to reason that the conclusion (the higher-level claim) is true when the premises (the lower-level claims) are true.

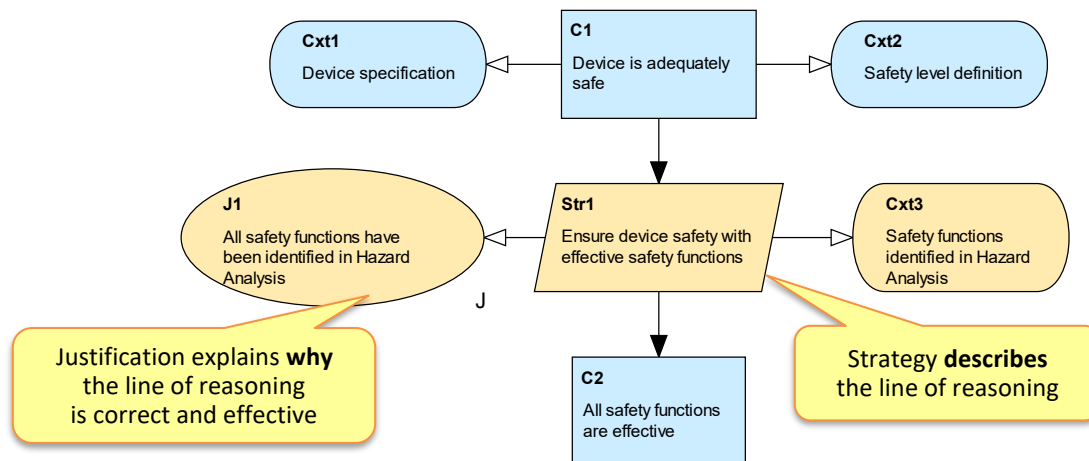


Figure 5. The reasoning step for the top claim (GSN)

A **strategy** specifies the inference rule used to reason that the conclusion (the higher-level claim) is true when the premises (the lower-level claims) are true.

A strategy is not a statement and it is not a predicate. It just identifies a rule we use to reason. You can say a strategy is like a recipe telling you how to take ingredients and combine them to bake a cake. The strategy says WHAT to do to support a given claim.

It will not always be clear that the selected strategy is right for a given claim in its context or that the strategy was implemented in the right way, for example if all steps of the strategy have been implemented. Therefore we add a justification (or a rationale) to state WHY we think the strategy is applicable and implemented in the right way.

Figure 5 presents the GNS diagram for the top level reasoning. The equivalent argument tree is presented in Figure 6.

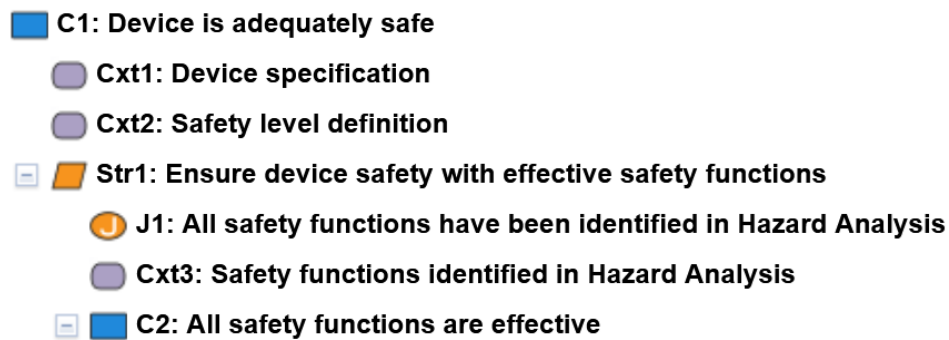


Figure 6. The reasoning step for the top claim

A **rationale** is a statement which justifies whether a valid strategy is used to support a given claim, and whether it is used in the right way. Being a statement a rationale is technically also a claim. A rationale does not have direct effect on the goal of the assurance case, that is in our example the rationale will not impact the safety of the device directly. The role of the rationale is to provide confidence that the reasoning supporting the device safety is correct.

Rationale has impact not on the validity of the goal of the argument, but it affects the **confidence** in the reasoning. The rationale will not say if the goal of the argument is achieved, for example if the system is adequately safe. It will say if we can trust the reasoning leading to the conclusion that the top claim of the argument is true. The assessment mechanism in PREMIS is described in our other white paper.

The claim C2 is not supported on the presented diagram. It will be supported in the next reasonings step. We can develop any number of sequential reasoning steps until we reach the level of base claims (facts) supported directly by evidence. To keep our argument simple we will define base claims in the next reasoning step.

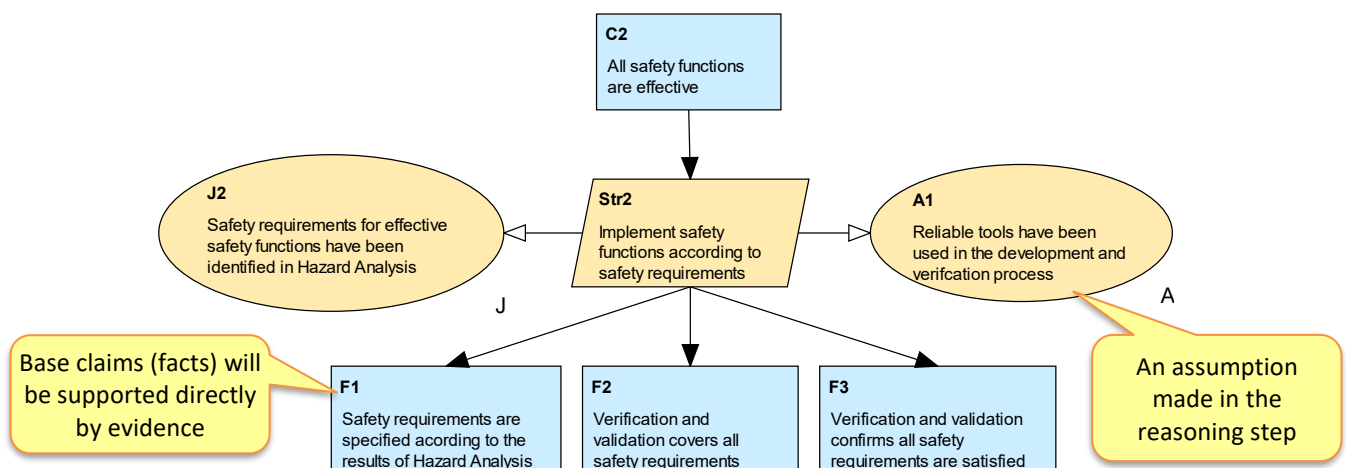


Figure 7. Argument for the implementation of safety functions (GSN notation)

We will demonstrate that the safety functions are effective by verification if they satisfy the allocated requirements. This will be done in steps: first we will demonstrate that we have a set of requirements for safety functions, then we will plan verification and validation (V&V) actions that will cover all the requirements and finally we will check that the V&V results confirm that the requirements are satisfied.

Sometimes in the argument we refer not only to claims that we plan to support with evidence, but also to some conditions that are **assumptions** for the reasoning. For example you may find that the tools used in the

development process may have an impact on the system safety, so we add assumption A1. You can also use assumptions to specify the context in which assurance case goals are to be demonstrated.

Each reasoning step has three layers as presented with the use of colours in Figure 7. Starting from the top layer of the step we define:

- the conclusion – a claim and optionally related context or assumptions,
- the reasoning – a strategy, its justification and optionally related assumptions,
- the premises – claims which will be supported by further reasoning or evidential steps.

5 The evidential step

The reasoning steps of an assurance case describe the logic, while the evidential steps describe relation to real world artifacts. All reasoning steps should be supported by evidential steps.

The basic schema of an evidential step consists of just two types of elements: base claims (facts) and references to evidence.

For the base claims presented in the previous section we can use the following documents produced in the device development process as evidence:

- Safety Requirements Specification which covers the required safety functions
- Test Plan which covers verification of the safety requirements
- Test Report

The evidential step for the device safety argument is presented in Figure 8.

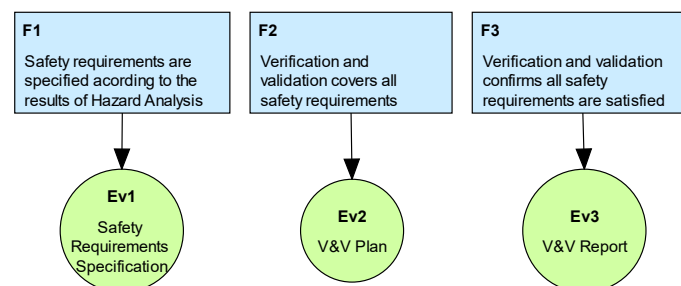


Figure 8. Evidential step for the device safety argument (GSN notation)

We may call elements on the diagram as “evidence” but in fact they are references to the evidence item. An **evidence item** is a piece of information represented in any form available for the assurance case users. In most of the cases it is an electronic document (like a PDF file) but it can also be a paper document.

If the evidence item is available online the reference in the argument may contain an URL address to let the argument users open it. The other solution is just to describe where the evidence item is located. This approach is commonly used for paper documents. In some cases, evidence may contain sensitive information which would not be included in the assurance case online and the reviewer has to get a physical access to it in order to make a review.

6 The complete sample argument model for device safety

We have discussed a sample assurance case for device safety step by step. In this section we present a complete argument using GSN and PREMIS notation.

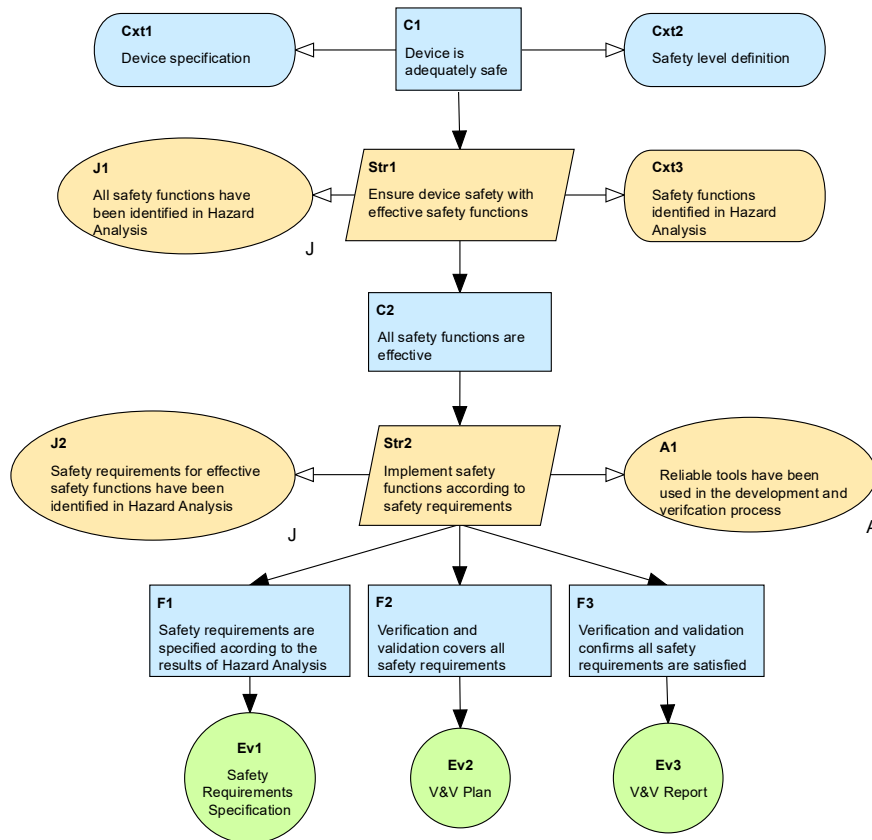


Figure 9. Complete argument for device safety (GSN notation)

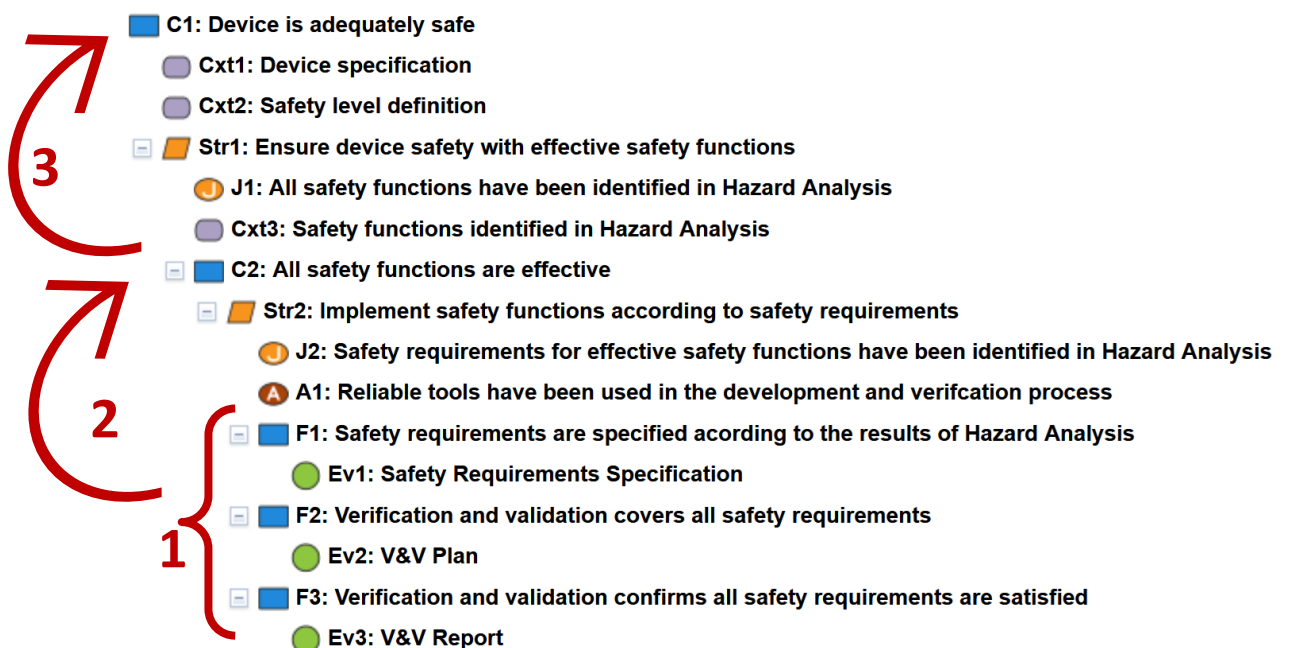


Figure 10. Complete argument for device safety (PREMIS notation)

7 Summary

In this guide we described the main elements of assurance case argument structure.

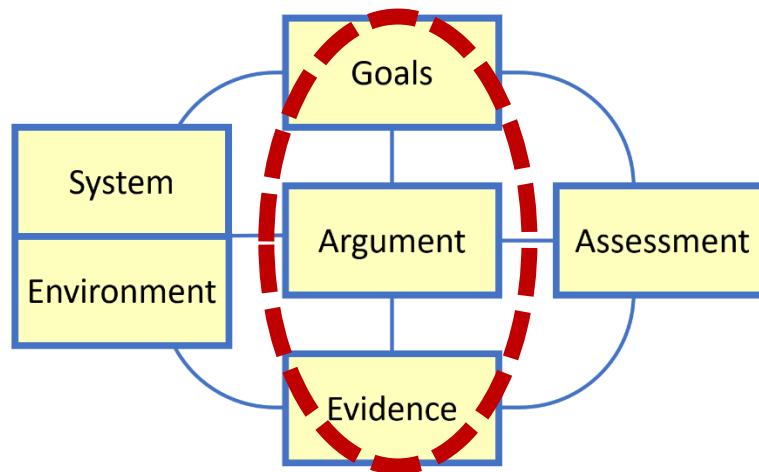


Figure 11. The main components of the assurance case

We used PREMIS to present an example of an assurance case.




















You can find more information on our website www.argevide.com and in the PREMIS manual.

Annex 1. Assurance case argument metamodel in PREMIS

PREMIS assurance case metamodel is compliant with ISO 15026-2 “Systems and Software Assurance — Part 2: Assurance Case” and partially implements OMG SACM metamodel version 2.3.

The model allows to implement three assurance case notations: GSN, CAE and TRUST-IT:

Table B1. Comparison of TRUST-IT, GSN and CAE argument models

| GSN | CAE | TRUST-IT |
|---|--|---|
|  Goal |  Claim |  Claim |
| | |  Fact (base claim) (*) |
|  Strategy |  Argument |  Argumentation Strategy |
|  Justification |  Side claim |  Rationale |
|  Solution |  Evidence |  Reference |
|  Assumption |  Assumed claim (**) |  Assumption |
|  Context |  Information |  Information |

(*) The TRUST-IT argument model distinguishes between claims that are supported by a strategy and a supporting argument and claims that are directly supported by evidence. The former is called a “base claim”. The word “base” plays informative role and is used to indicate that a given claim is supported directly by evidence

(**) The type of assumption element is not specified in the CAE argument model.

The general metamodel of PREMIS argument structure is presented in Figure 12.

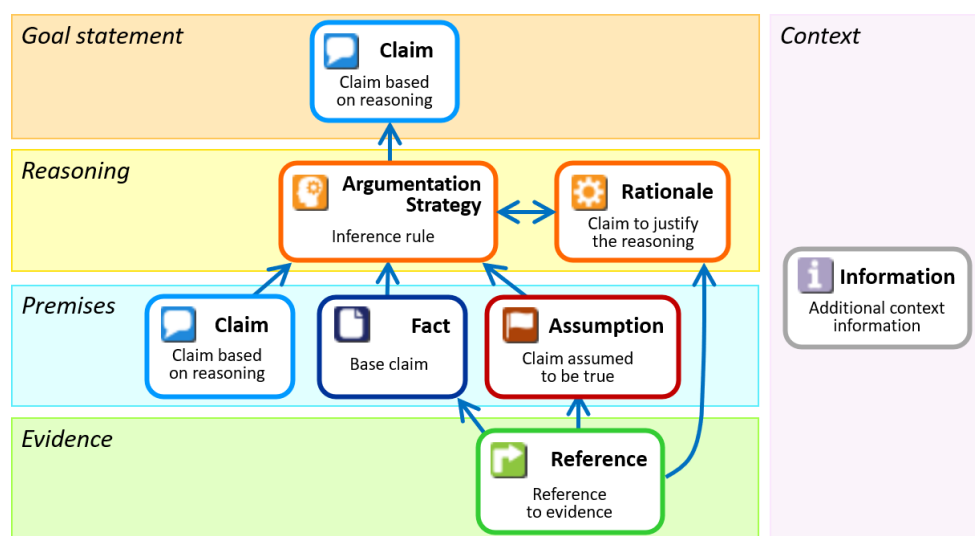









Figure 12. PREMIS argument metamodel

Arrows on the diagram denote support. For example, a claim is supported by a strategy. An element at the beginning of an arrow provides support for the element at its end.

1. The goal statement is a **claim**. It is a predicate (a true-false) statement which states the goal to be supported.
2. Reasoning is implemented by:
 - a) an **argumentation strategy** which specifies the line of reasoning and

- b) **rationale** with justifies that the strategy is correct and applicable for a given claim and also that it is was correctly applied.
- 3. A premise can be:
 - a) a **claim** that is to be supported by another argumentation strategy and further premises or
 - b) a **fact** (base claim) supported directly by evidence, or
 - c) an **assumption** that we make in the argument.
- 4. Evidence which supports the premises:
 - a) **references** to evidence artefact, usually documents but other media like photos or measurement data may also be used.
- 5. The context **information** may be provided to ensure precise interpretation of argument elements.

All the PREMIS assurance case elements are listed in the table below:

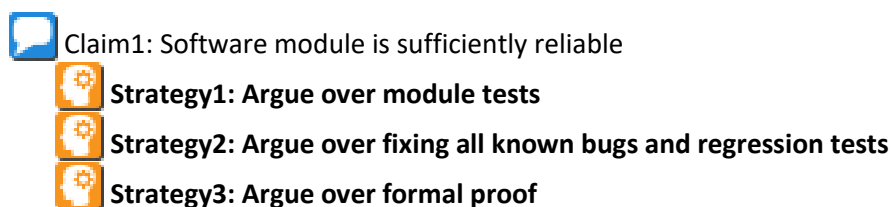
| Icon | Name | Definition |
|---|-------------------------------|--|
|  | Claim | A statement about some property that requires argumentation and evidence to demonstrate that the system satisfies it. |
|  | Argumentation Strategy | Strategy specifies the inference rule that uses the supporting premises to conclude that the claim is satisfied. Note: Strategy used to refute a claim (to conclude that it is not satisfied) is called a counter-argumentation strategy. |
|  | Rationale | A statement that justifies validity of the reasoning set down for a given claim by the argumentation strategy. |
|  | Assumption | A statement about some property, assumed to be true without any argument or evidence, usually assured by the environment. |
|  | Fact (base claim) | A statement about some property supported directly by evidence. Note: Facts are a type of claims that don't need any argumentation step and evidence is sufficient to demonstrate they are satisfied. |
|  | Reference | A reference to the evidence to support the argument. |
|  | Information | Additional description for the argument element that supplements its definition. |

PREMIS argument structure should follow the rules described in the following subsections.

7.1 Each claim is supported by one or more strategies

PREMIS notation requires each claim to be supported by at least one argumentation strategy. You cannot support a claim directly with other claims. Each reasoning step should be defined with the use of argumentation strategy and justified with a rationale.

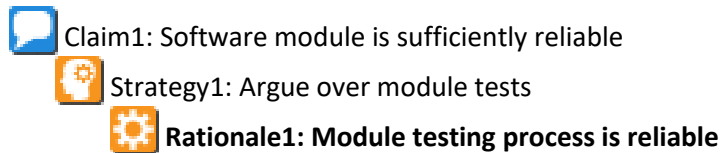
More than one strategy can be defined for a claim to represent independent ways of reasoning.



Note: a base claim, that is, a claim supported directly by evidence is distinguished as a separate type “fact”.

7.2 A rationale is provided for each strategy

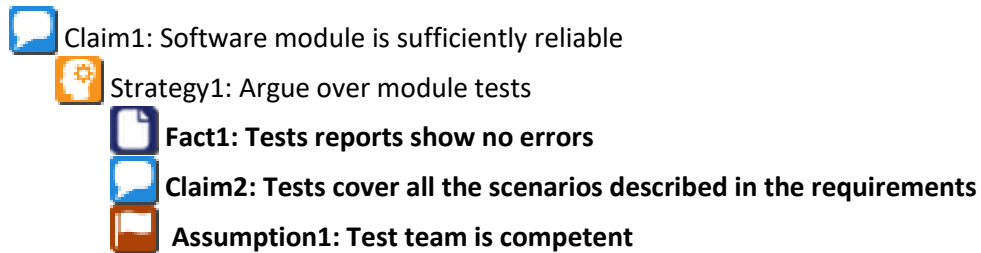
A rationale is to be specified for each strategy to justify that the strategy is correct and applicable for a given claim and that it is was correctly applied.



A rationale is a predicate (a true/false statement) like a claim. It can be supported by evidence or by arguments when necessary.

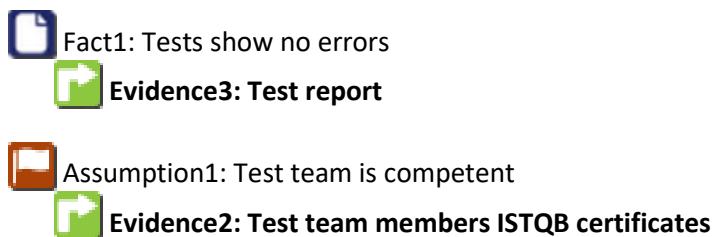
7.3 Argumentation strategy is supported by an arbitrary number of premises (facts, claims and/or assumptions)

A strategy should be supported by one or more premises. A premise can be a fact, an assumption or a claim.



7.4 Facts and assumptions are supported directly by references to the evidence

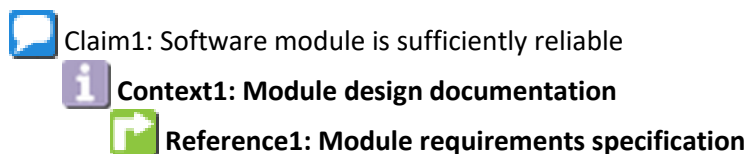
Facts and assumptions can be supported by evidence.



Providing evidence for facts is mandatory in PREMIS, while evidence for assumptions is optional.

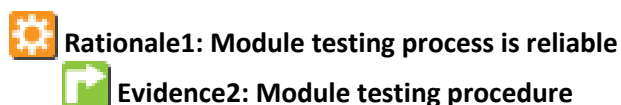
7.5 Information elements can be attached to any other elements

Additional information like context data can be attached to any elements in the assurance case. Such information element can be supported by references to documentation when needed.






7.6 Rationale can be supported by evidence or an argument

Rationale elements can be supported either by an external evidence or by an explicit argument (a confidence argument) if a detailed argumentation is needed to build confidence in the rationale.



7.7 Linking argument elements

Some argument elements, for example references to evidence, can provide support for more than one argument element. Presenting assurance cases in a hierarchical way is a simplification and an argument is really a directed graph, not a hierarchical tree.

When one element is to be used more than once we can use links. Links are marked with a small black arrow in their icons:   . You can create links to any argument element except rationales.

