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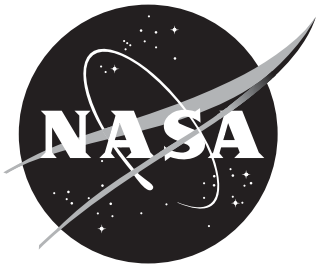

The Simple Assurance Argument Interchange Format (SAAIF) Manual

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June 2018

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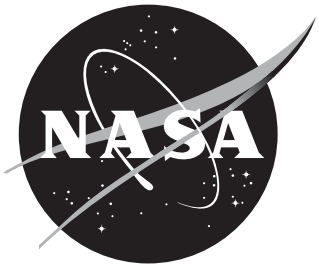

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Abstract

This document describes the Simple Assurance Argument Interchange Format, a proposed meta-model for describing structured assurance arguments. We describe the syntax and semantics of the model elements, compare the meta-model to existing argument formats, and give an example to illustrate its use.

1 Introduction

Assurance cases are variously defined. One prototypical definition of a *safety case*—an assurance case specifically focused on safety—states that a "Safety Case consists of a structured argument, supported by a body of evidence that provides a compelling, comprehensible and valid[1] case that a system is safe for a given application in a given environment" [1]. Writers have recorded assurance arguments in a number of different formats:

- Structured and freeform prose text [2, 3]
- Tables [3]
- Graphical argument formats such as Goal Structuring Notation (GSN) and Claims-Argument-Evidence models (CAE) [4, 5]
- Combinations of symbolic and natural-language logic [6–8]

The related philosophy literature includes yet more formats, including Toulmin structures and Wigmore diagrams among many others [9–11].

In 2013, the Object Management Group (OMG) published the first version of the Structured Assurance Case Metamodel (SACM) [12]. Some observers cited the metamodel's complexity as a hindrance to widespread adoption. Work then began on a replacement version that was meant to be simpler. A beta of SACM version 2.0 was released in 2016 and later refined [13]. The final version of SACM version 2.0 was released in March 2018 [14].

Taking inspiration from automobile designer Colin Chapman's exhortation to "simplify, then add lightness," we wondered whether a metamodel could be simpler than the SACM yet still serve the purposes of assurance argumentation. This document presents a candidate answer inspired by the SACM and, to a lesser degree, by GSN and Toulmin's model [5, 9, 14]. We call our metamodel the Simple Assurance Argument Interchange Format (SAAIF).

1.1 Design goals

Our design goals for the SAAIF are that it should:

1. Serve the purposes to which assurance arguments are typically put
2. Be simple enough that a class diagram fits legibly on one sheet of paper
3. Have semantics described well enough to permit argument analysis

[1] This restrictive clause yields unexpected effects. For example, C. M. Holloway observes that if an assurance case is reviewed and found not compelling, it ceases to qualify as a case.

It is worth noting with respect to the first of these that there appears to be several different assurance argument schools of thought [15]. We are concerned here primarily with purposes that involve communication from the writer to many safety stakeholders, such as telling the story of how a system or service achieves the properties to be assured. As one regulator put it,

> A safety case is a logical and hierarchical set of documents that describes risk in terms of the hazards presented by the facility, site and the modes of operation, including potential faults and accidents, and those reasonably practicable measures that need to be implemented to prevent or minimise harm. It takes account of experience from the past, is written in the present, and sets expectations and guidance for the processes that should operate in the future if the hazards are to be controlled successfully. The safety case clearly sets out the trail from safety claims through arguments to evidence [16].

Achieving this purpose requires clear and preferably precise communication to human readers, who might have different backgrounds and different technical capabilities. Again, quoting the same regulator:

> The primary purpose of a safety case is to provide the licensee with the information required to enable safe management of the facility or activity in question. Therefore it should be understandable to and useable by those with direct responsibility for safety [17].

Accordingly, in reducing the SACM to create the SAAIF we have favored clear, human-readable expression over other considerations that other researchers have addressed, such as deductive validity or computable confidence [8, 18].

Whether the SAAIF meets the goals identified above or not is not a matter we have addressed in depth. We present no concrete efficacy hypotheses here, much less valid empirical evidence of efficacy. The purpose of this document is merely to present the SAAIF for further discussion and study, not to present an assessment of it.

1.2 Document conventions

Sections 2 and 3 present a definition of the SAAIF. All subsections are normative unless otherwise marked. Appendices A–C present mappings between the SAAIF and GSN, Toulmin's model, and confidence maps. Appendix D presents an example argument taken from NASA's *Explicate '78* work in order to illustrate how the SAAIF might be used.

Where terms from the model are used in the text, they are typeset `like this` and hyperlinked to their definitions where possible.

2 Model

Figure 1 depicts a UML model of the Simple Assurance Argument Interchange Format. Briefly:

- Each instance of the `AssuranceCase` class (Section 2.16) represents an assurance case. Each assurance case comprises an arbitrary number of `Glossary`, `Argument`, and `Inventory` objects.
- Each instance of the `Glossary` class (Section 2.7) represents a set of term definitions to be used within the assurance case. Each definition is represented by an instance of the `Definition` class (Section 2.6). These definitions can be cited in a machine-readable manner from within the `EscapedString` fields used to specify the text of the argument.
- Each instance of the `Argument` class (Section 2.15) represents a self-contained fragment of argument. Arguments comprise an arbitrary number and mix of `Claim`, `EvidenceReference`, and `Inference` objects.

  - Each `Claim` object (Section 2.12) represents a single claim.
  - Each `EvidenceReference` object (Section 2.13) represents a citation of evidence.
  - Each `Inference` object (Section 2.14) describes how a set of claims or evidence references serves as premises to show the truth of one or more claims or inferences.

  The abstract `ArgumentElement` class (Section 2.11) provides a common base class for claims, evidence references, and inferences.
- Each instance of the `Inventory` class (Section 2.10) represents a collection of named entities that can be discussed within the argument (e.g., cited as evidence). The inventory comprises an arbitrary number of `Artifact` objects (Section 2.8). Relationships between artifacts—e.g., cases where one artifact is derived, at least in part, from another, or when one artifact comprises others—may be documented using instances of the `ArtifactRelationship` class (Section 2.9).
- The `ModelElement` class (Section 2.5) provides a common abstract base class for most SAAIF classes.
- The `EscapedString` class (Section 2.2) encodes text that might reference other model elements in a machine-readable manner.
- Instances of the `Identifier` class (Section 2.1) serve to identify model elements.
- Instances of the `KeyValuePair` class (Section 2.4) are used to annotate model elements. Each pair's value comprises a set of objects derived from the abstract `Value` class (Section 2.3). The SAAIF metamodel defines the `EscapedStringValue` (Section 2.3.1), (plain) `StringValue` (Section 2.3.2), and `BooleanValue` (Section 2.3.3) types. Users may define other value types as needed.

The following sections explain each of the model's classes in turn.

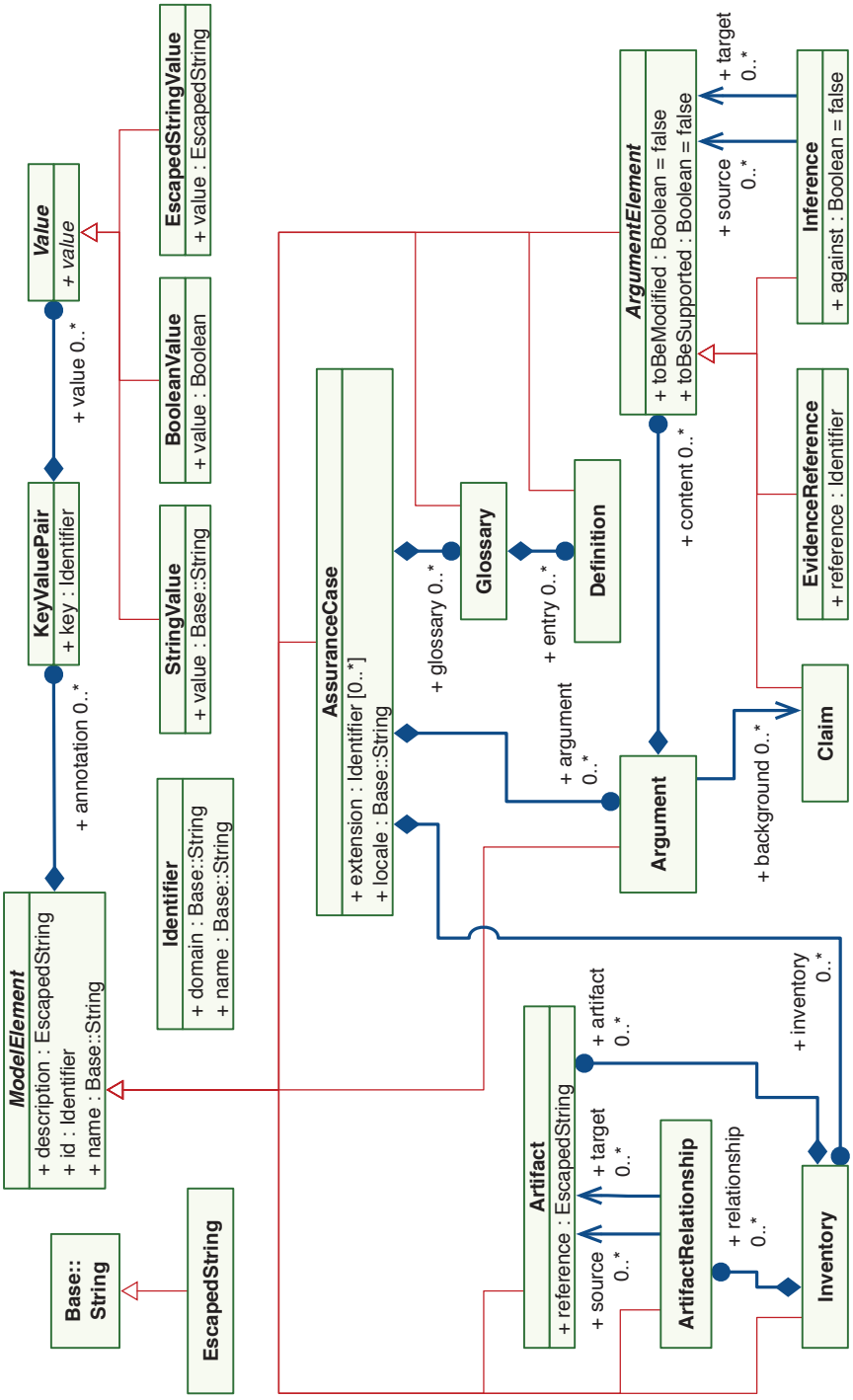


Figure 1: *UML model of the Simple Assurance Argument Interchange Format.*

2.1 The Identifier class

An `Identifier` is a human-readable identifier for `AssuranceCase` extensions and objects of the `Definition`, `KeyValuePair`, `ModelElement`, and derived classes.

Derivation. The `Identifier` class is not derived from any other classes. No classes derive from `Identifier`.

Fields and relationships. This class's fields and relationships are:

- `domain : Base::String` — An optional qualifier for identifiers that permits disambiguating between two identifiers with equal `name` fields. The `domain` string comprises a string of arbitrary length. The `domain` '`SAAIF`' is reserved.
- `name : Base::String` — A human-readable name for an identified object comprising a string of arbitrary length.

Semantics. An `Identifier` and any `ModelElement` or `KeyValuePair` it identifies is said to be *anonymous* if the `name` field of the `Identifier` is empty. An `Identifier` is said to be *unqualified* if its `domain` is empty but its `name` is not. A reference `Identifier` i_R *matches* an identified object's `Identifier` i_T iff both their `name` and `domain` fields are equal.

Invariants. All instances must satisfy the following invariants:

1. The `domain` and `name` strings must comprise only characters from the set {'`a`',...,'`z`','`A`',...,'`Z`','`0`',...,'`9`','`_`'}.

(See Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). For compactness, some user agents might choose to display `name` fields but not `domain` fields, especially for objects with a `name` field is unique in the model.

2.2 The EscapedString class

An `EscapedString` is a string in which special character sequences represent machine-readable references to instances in a model of classes derived from `ModelElement` (e.g., `Definition`).

Derivation. The `EscapedString` class is a special form of a plain Unicode string (represented as `Base::String` in this document). No classes derive from `EscapedString`.

Fields and relationships. None.

Semantics. String values should be interpreted literally with the exceptions given in Table 1. Machine-readable references to objects of types derived from `ModelElement` are given by specifying their identifiers enclosed within dollar signs (‘`$`’). User agents might render these as hyperlinks to the referenced `ModelElement`. If the reference includes specific *display* text, user agents should render a reference as that display text. Otherwise, user agents should render references as though they had been replaced by the `name` of the *matching* `ModelElement`.

Table 1: *Escape sequences for* `EscapedString` *objects.*

String	Interpretation
‘`\\`’	‘`\`’
‘`\$`’	‘`$`’
‘`$`⟨*domain*⟩`.`⟨*name*⟩`$`’	The `name` of the `ModelElement` with the matching `id`. User agents might hyperlink this text.
‘`$`⟨*domain*⟩`.`⟨*name*⟩`:`⟨*display*⟩`$`’	‘⟨*display*⟩’. Useful where it is necessary to change the referenced text’s number, tense, etc. User agents might hyperlink this text.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.3 The Value class and its subclasses

An object of a type derived from the abstract `Value` class represents a specified value—e.g., the value of an annotation to a model element represented by a `KeyValuePair`.

Derivation. The `Value` type is not derived from any other classes. The SAAIF metamodel defines three sub-classes of `Value`: `StringValue`, `EscapedString-Value`, and `BooleanValue`. Users may derive other classes as needed.

Fields and relationships. The `Value` class’s fields are:

- `value` — All subclasses of `Value` have a `value` field of the appropriate type to specify their value.

Semantics. Represents the given value.

Invariants. None.

Remarks (non-normative). None.

2.3.1 The EscapedStringValue class

The `EscapedStringValue` class embodies a `Value` in the specific case where its `value` field is a `EscapedString`.

2.3.2 The StringValue class

The `StringValue` class embodies a `Value` in the specific case where its `value` field is a simple Unicode string.

2.3.3 The BooleanValue class

The `BooleanValue` class embodies a `Value` in the specific case where its `value` field is a Boolean.

2.4 The KeyValuePair class

Instances of the `KeyValuePair` class represent named sets of objects derived from `Value`. `KeyValuePair` objects are used to annotate objects of types derived from `ModelElement`.

Derivation. The `KeyValuePair` type is not derived from any other classes. No other classes are derived from `KeyValuePair`.

Fields and relationships. This class's fields and relationships are:

- `key : Identifier` – Identifies the `KeyValuePair`.
- `value : Value` — Gives the `KeyValuePair`'s values (if any).

Semantics. The presence of a `KeyValuePair` *a* in the `annotation` set of a `ModelElement` *e* indicates that *e* has a property with a name given by *a*'s `key` and a value given by *a*'s `value`. Some extensions may define special meanings for given `key` identifiers (see Section 3). Table 2 defines the pre-defined `key` values for `KeyValuePair` objects and the corresponding meanings.

Invariants. All instances must satisfy the following invariants:

1. The `key`'s `name` must not be empty.

(See Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). The `IntantiationNote` `key` might seem duplicative of the `Note` `key` since both permit decorating `ModelElement`s with arbitrary human-readable text notes. The purpose of distinguishing the former from the latter is to allow a form of remove-before-operation checking for pattern instantiation. See the description of the `strict` extension in Section 3.1.

Table 2: *Pre-defined kinds of* `KeyValuePair` *instances.*

key (domain.name)	**value type**	**Description**
`SAAIF.InstantiationNote`	`EscapedStringValue [0..*]`	Arbitrary human-readable text comments about how to instantiate an argument pattern.
`SAAIF.IsPattern`	`BooleanValue [1]`	If `true`, indicates that the decorated `Argument` or `Glossary` is or is associated with a pattern.
`SAAIF.Note`	`EscapedStringValue [0..*]`	Arbitrary human-readable text comments about the `ModelElement`.

2.5 The ModelElement class

The abstract `ModelElement` class is a base class providing common features for most of the classes used to model assurance arguments and assurance cases.

Derivation. The `ModelElement` class is not derived from any other classes. Several classes derive from `ModelElement`: `Argument`, `ArgumentElement` (and, indirectly, its derived classes `Claim`, `EvidenceReference`, and `Inference`), `Artifact`, `ArtifactRelationship`, `AssuranceCase`, `Definition`, `Glossary`, and `Inventory`.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` — A set of a `KeyValuePair` objects that provide more information about the `ModelElement`. For example, writers might attach freeform comments to a `ModelElement` using a `KeyValuePair` with `key=SAAIF.Note` (see Section 2.4).
- `description : EscapedString` — A human-readable description of the `ModelElement`. Given as a `EscapedString` so as to encode machine-readable references to objects of the `Definition` class or a class derived from `ModelElement`. May be empty unless prohibited by the subclass.
- `id : Identifier` — A machine-readable `Identifier` for the `ModelElement`. May be anonymous (see Section 2.1) unless prohibited by the subclass.
- `name : Base::String` — A human-readable identifier for the `ModelElement`. May be blank unless prohibited by the subclass.

Semantics. None.

Invariants. All instances must satisfy the following invariants:

1. The `name` and `description` fields may not contain whitespace other than space characters and may not begin or end with whitespace.

2. The `name` field may not contain two or more adjacent space characters.

(See Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). A `ModelElement`'s `name` is typically short: a few words at most. It's `description` may be longer: a phrase or sentence. Narrative text explanations are typically relegated to notes attached as an `annotation` (see Section 2.4).

2.6 The Definition class

A `Definition` defines a term of art for an assurance case.

Derivation. The `Definition` class is derived from the `ModelElement` class. No classes are derived from the `Definition` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `description: EscapedString` (*inherited from* `ModelElement`) — The definition of the term.
- `id : Identifier` (*inherited from* `ModelElement`) — An identifier for the `Definition`. This can be used to refer unambiguously to the `Definition` from within an `EscapedString`.
- `name : Base::String` (*inherited from* `ModelElement`) — The term to be defined.

Semantics. Definitions have scope throughout the `AssuranceCase` they are defined in. Wherever it is used, the defined term (and derivatives such as plural forms) should be read as though it had the meaning specified by in the `description` (mutatis mutandis). While definitions may be explicitly referenced in any `EscapedString` (including the `description` of a term), the definitions in an `AssuranceCase` apply to all uses of defined terms whether or not they are referenced explicitly.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.7 The Glossary class

A `Glossary` defines a set of terms of art for an assurance case.

Derivation. The `Glossary` class is derived from the `ModelElement` class. No classes are derived from the `Glossary` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement`) — See Section 2.5.
- `entry : Definition [0..*]` — The set of entries within the `Glossary`.
- `i : Identifier` (*inherited from* `ModelElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement`) — See Section 2.5.

Semantics. Defines a set of terms.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.8 The Artifact class

An `Artifact` object identifies an artifact of significance to the assurance argument.

Derivation. The `Artifact` class is derived from the `ModelElement` class. No classes are derived from the `Artifact` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement`) — Describes the artifact, answering the question, *What kind of thing is it?*
- `id : Identifier` (*inherited from* `ModelElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement`) — Identifies the artifact, answering the question, *What is it called?*
- `reference : EscapedString` — Identifies the artifact, answering the question, *Which instance of* < kind of thing > *is it?* Might be empty.

Semantics. An `Artifact` object identifies a thing. Two or more `Artifact` objects might identify the same thing or parts of the same thing. (A writer might model such relationships using the `ArtifactRelationship` class.)

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.9 The ArtifactRelationship class

An `ArtifactRelationship` asserts a relationship between artifacts.

Derivation. The `ArtifactRelationship` class is derived from the `ModelElement` class. No classes are derived from the `ArtifactRelationship` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement`) — A description the relationship between the artifacts identified by `source` and the artifacts identified by `target`.
- `id : Identifier` (*inherited from* `ModelElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement`) — See Section 2.5.
- `source : Artifact [0..*]` (*reference*) — The `Artifact` objects on one side of the relationship.
- `target : Artifact [0..*]` (*reference*) — The `Artifact` objects on the other side of the relationship.

Semantics. Each `source` is related to each `target` as specified by the `description`.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). The `source` and `target` sets are not required to be disjoint. This because some relationships are bi-directional. For example, a writer might document the fact that a set of artifacts were all produced by the same developer(s) using an `ArtifactRelationship` with `source=target` and a description reading, "Produced by same developer as."

We considered adding additional inventory-related classes to record, e.g., the provenance of artifacts. But these relationships can be described to human readers using `ArtifactRelationship` objects. For example, one might model a process description as an `Artifact` and use an `ArtifactRelationship` to record that another artifact was "produced using the process described in" the former artifact. If a user wishes to automate support for re-examining artifacts that might have been impacted by a change, the `extension` and `annotation` mechanisms could be used to indicate which `ArtifactRelationship` objects signify dependence between `Artifact` objects.

2.10 The Inventory class

An `Inventory` defines a set of `Artifact`s and their `ArtifactRelationship`s (if any).

Derivation. The `Inventory` class is derived from the `ModelElement` class. No classes are derived from the `Inventory` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `artifact : Artifact [0..*]` — Defines the set of `Artifact` objects in this `Inventory`.
- `description : EscapedString` (*inherited from* `ModelElement`) — See Section 2.5.
- `id : Identifier` (*inherited from* `ModelElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement`) — See Section 2.5.
- `relationship : ArtifactRelationship [0..*]` — Defines the set of relationships amongst the invetory's artifacts.

Semantics. An `Inventory` is a container of `Artifact` objects and `ArtifactRelationship` objects documenting the relationships amongst them. No universal meaning applies to the separation of `Artifact` objectss into separate `Inventory` containers, but those containers' `description` fields might indicate such a purpose.

Invariants. All instances must satisfy the following invariants:

1. If an `Inventory` *i*'s `relationship` set contains an `ArtifactRelationship` *r* with a `source` or `target` containing `Artifact` *a*, *i*'s `artifact` set must also contain *a*.

(See Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.11 The ArgumentElement class

`ArgumentElement` serves as a common base class for the classes used to model the contents of an `Argument`.

Derivation. The `ArgumentElement` class is derived from the `ModelElement` class. `ArgumentElement` is the abstract base class from which the `Claim`, `EvidenceReference`, and `Inference` classes are derived.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.

- `description : EscapedString` (*inherited from* `ModelElement`) — A description of the `ArgumentElement`. User agents might display this as the element's text content.
- `id : Identifier` (*inherited from* `ModelElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement`) — The name of the `ArgumentElement`. User agents might display this as an identifier.
- `toBeModified : Boolean = false` — Indicates that the element requires further modification. For example, a pattern might set this field to `true` in one of its `Claim` objects to indicate that the user should modify the `description` to suit the application. A writer producing a draft assurance case might set this field to `true` to indicate that an `ArgumentElement` might require revisiting later.
- `toBeSupported : Boolean = false` — Indicates that the element requires further support. For example, a pattern might set this field to `true` in one of its `Claim` objects to indicate that the user instantiating the element should supply premises that are appropriate for the application and link these via one or more `Inference` objects. A writer producing a draft assurance case might mark an `Inference` this way to indicate an intent to later supply a warrant and backing.

Semantics. The semantics of an `ArgumentElement` vary according to whether it is an `Inference`, `EvidenceReference`, or `Claim`.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.12 The Claim class

A `Claim` represents a proposition that the argument writer asserts is true. A claim might be assumed (i.e., deliberately not supported by evidence either directly or indirectly), a conclusion, or a premise.

Derivation. The `Claim` class is derived from the `ArgumentElement` class. No classes are derived from the `Claim` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement` *via* `ArgumentElement`) — Specifies the proposition to be asserted.
- `id : Identifier` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.

- `name : Base::String` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `toBeModified : Boolean = false` (*inherited from* `ArgumentElement`) — See Section 2.11.
- `toBeSupported : Boolean = false` (*inherited from* `ArgumentElement`) — See Section 2.11.

Semantics. The existence of a `Claim` in an `Argument` indicates the writer's contention that the proposition recorded in the `description` field of that `Claim` is true. A `Claim` is *assumed* (at least for the moment) if it does not appear in the `target` of at least one `Inference` with `against=false`.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). None.

2.13 The EvidenceReference class

An `EvidenceReference` represents the citation of an evidence-related item as a premise.

Derivation. The `EvidenceReference` class is derived from the `ArgumentElement` class. No classes are derived from the `EvidenceReference` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement` *via* `ArgumentElement`) — A description of the evidence-related item. If this is blank and `reference` matches the `id` of an `ModelElement`, the `description` of that `ModelElement` can be taken as the item's description.
- `id : Identifier` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `reference : Identifier` — The (optional) `id` of the evidence-related item in question—e.g., an `Artifact` or another `Argument` (if the item is represented in the model). Empty `name` and `domain` fields signify that referenced item is not modeled.
- `name : Base::String` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `toBeModified : Boolean = false` (*inherited from* `ArgumentElement`) — See Section 2.11.
- `toBeSupported : Boolean = false` (*inherited from* `ArgumentElement`) — See Section 2.11.

Semantics. Identifies an evidence-related item. The `Inference` in which the `EvidenceReference` appears as a `source` defines how the item serves as evidence [19].

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). It is tempting to require that if `reference` is empty, `toBeSupported` must be `true`. We deliberately do not make this restriction. Writers are free to simply describe the evidence item using the `description` field. Writers are also free to use the `description` field in addition to the `reference` relationship in order to cite only part of a modeled item.

We considered allowing `EvidenceReference` objects to refer to specific elements contained by other `Argument` objects. This is disallowed in the `Strict` extension (see Section 3.1) so as to force readers to consider the context of both arguments when determining whether one supports a claim made in the other.

2.14 The Inference class

An `Inference` represents an inference from premises, which might comprise evidence, assumptions, or claims backed by further argument.

Fields and relationships. This class's fields and relationships are:

- `against : Boolean = false` — Indicates that the premises tend to show that all claims in the `target` set are false and any inferences in the `target` set do not hold.
- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement` *via* `ArgumentElement`) — Describes the nature of the inference (i.e., how the premises support the claims and inferences identified by `target`. For example, in an inference from one or more `EvidenceReference` objects to a `Claim`, the `description` might identify or describe an evidence scheme [19].
- `id : Identifier` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement` *via* `ArgumentElement`) — See Section 2.5.
- `toBeModified : Boolean = false` (*inherited from* `ArgumentElement`) — See Section 2.11.
- `toBeSupported : Boolean = false` (*inherited from* `ArgumentElement`) — See Section 2.11.

Semantics. The assertion of an `Inference` from the elements in `source` to the elements in `target` indicates the writer's contention that the sources collaboratively support (or weigh against) each `target` in the same way. Premises that support a target or targets in similar fashion should do so through separate `Inference` objectss, even if the support is not fully independent. That is, the removal of a premise from the `source` set should change what is known about the nature of the inference, not merely alter the confidence it lends (or takes from) the targets. For a comparison to Toulmin's model of argumentation, see Appendix B.

Invariants. All instances must satisfy the following invariants:

1. The `source` set must not contain any `Inference`s.
2. The `target` set must not contain any `EvidenceReference`s.
3. If `source` is empty, `toBeSupported` must be `true`.
4. If `target` is empty, `toBeModified` must be `true`.

(See Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). It is tempting to assert that the `source` set and `target` set should be homogenous (e.g., contain only `Claim` objects) on the grounds that inference from or two a heterogeneous set seems likely to be the result of an error or misuse. We make no such prohibition. However, readers and reviewers are reminded that `Inference` objects are meant to record coherent, collaborative support (or challenge). We cannot conclude that there are no inferences from mixed sources that would qualify, but if there are, we would not preclude recording them.

2.15 The Argument class

The `Argument` class represents a self-contained argument or argument pattern. `Argument` objects may reference artifacts and terms defined in the same `AssuranceCase`.

Derivation. The `Argument` class is derived from the `ModelElement` class. No classes derive from the `Argument` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `background : Claim [0..*]` (*reference*) — The set of claims—assumed or supported—to be taken as true throughout the argument.
- `content : ArgumentElement [0..*]` — The set of claims, evidence references, and instances that the argument comprises.
- `description : EscapedString` (*inherited from* `ModelElement`) — A description of the argument or argument pattern.

- `id : Identifier` (*inherited from* `ModelElement`) — See Section 2.5.
- `name : Base::String` (*inherited from* `ModelElement`) — See Section 2.5.

Semantics. The argument should be interpreted as if the `background` claims were true. If the assumed claims—either in the `background` or asserted in the argument—are true, the `Argument` should be taken as support for its non-assumed claims. The nature and degree of the support for a given claim depends on the truth or assumptions and the strength of the evidence and inferences that directly or indirectly support that claim.

Invariants. All instances must satisfy the following invariants:

1. `background` must be a subset of `content`.

Remarks (non-normative). The `Argument` class lacks identification for 'top-level' `Claim` objects. If it is important to identify a particular `Claim` as having particular significance within a system safety assurance or certification effort, this can be done with its `id` or `description` or a `Note` annotation (if present).

The `Argument` class also lacks any means of distinguishing between 'public' (i.e., can be referenced from other arguments) and 'private' (i.e., cannot be referenced) elements. This distinction is not meaningful since arguments can only cite other arguments in toto.

2.16 The AssuranceCase class

`AssuranceCase` is the main container of the Simple Assurance Argument Interchange Format. Each `AssuranceCase` represents a collection of arguments and evidence.

Derivation. The `AssuranceCase` class is derived from the `ModelElement` class. No classes derive from the `AssuranceCase` class.

Fields and relationships. This class's fields and relationships are:

- `annotation : KeyValuePair [0..*]` (*inherited from* `ModelElement`) — See Section 2.5.
- `description : EscapedString` (*inherited from* `ModelElement`) — See Section 2.5.
- `extension : Identifier [0..*]` — Identifies any extensions that the model implements. See Section 3 for the definition of extensions.
- `glossary : Glossary [0..*` — The glossary or glossaries for terms used in the assurance case. When multiple glossaries are supplied, all definitions are available for use in all arguments within the case.
- `id : Identifier` (*inherited from* `ModelElement`) — An optional `Identifier` for the assurance case as a whole. Used to refer to cases defined in other models. May have empty `domain` and `name` fields.

- `inventory : Inventory [0..*]` — The collection(s) of `Artifact` objects that may be referred to by the case's argument(s). Where multiple inventories are supplied, all artifacts are available for reference from all arguments within the case.
- `locale : Base::String` — The ISO 15897 locale for the assurance case (e.g., "`en_US`"). May not be empty.
- `name : Base::String` (*inherited from* `ModelElement`) — See Section 2.5.

Semantics. Each `AssuranceCase` represents an assurance case, complete with definitions of any terms of art and references to any cited evidence. The scope of an assurance case is not limited to any particular stakeholder's perspective, the whole or part of any system or service, or any particular dependability properties. The `description` and any notes (see Section 2.5) may be used to describe the scope of the assurance case for the reader's benefit.

Invariants. None. (But see Section 3.1 for invariants related to the `Strict` extension.)

Remarks (non-normative). Having only one locale for the entire assurance case implies that all text within it is treated by the rules of a single language. This does not preclude including content from other languages. For example, an argument written in English might include German artifact names.

This restriction effectively precludes including translations of a single case within the same model. This is by design. Were cases to include content in multiple languages, the cost would be at least two forms of additional complexity: First, the model elements themselves would require locale fields. Second, and more importantly, the model would require a mechanism for guiding arbitration of meaning by identifying which version of the content was canonical and which versions are translations of that canonical content.

3 Extensions

Extensions are declarations that the writer can add to a model to indicate the adoption of additional invariants or model elements. Coupled with the ability to define arbitrary `KeyValuePair` annotations, extensions allow users to customize and extend the format. For example, one could define an extension for argument reviewing that used annotations to record which argument steps had been reviewed and record any issues noted during review. The SAAIF has one built-in extension: `SAAIF.Strict`.

3.1 SAAIF.Strict

The SAAIF model described in Section 2 deliberately permits models with detectable structural flaws such as circular arguments. This permissiveness serves an important design aim, namely allowing the writer to record work

in progress. The `SAAIF.Strict` extension includes additional invariants that preclude these structural flaws.

An `AssuranceCase` whose `extension` set includes an `Identifier` matching `SAAIF.Strict` must satisfy the following additional invariants:

1. The `AssuranceCase` must have at least one `Argument`, at least one `Glossary`, and at least one `Inventory`, but each of these may be empty.
2. The `Identifier` of each identified object must be unique. That is, no two identifiers used as (i) a `Definition`'s `key` or (ii) a `ModelElement`'s `id` may match.
3. Term definitions must be unique and well-defined. That is:
   (a) A `Definition` object's `name` and `description` fields must not be empty.
   (b) No two `Definition` objects in the same `Glossary` may have the same `name`.
   (c) A `Definition` object's `description` may not refer to another term that is directly or indirectly defined in terms of that definition. (Mechanical checking of strict conformance should interpret the appearance of an `Identifier` matching term a in term b's `Definition` as b being defined in terms of a.)
4. Inferences must be valid. That is:
   (a) An `Inference` object's `source` set must not be empty.
   (b) An `Inference` object's `target` set must not be empty.
   (c) No two `ArgumentElement` objects may participate in a circular reference. More formally, $\neg supports(a,a)$ where $supports(a,b)$ indicates that either (a) there exists an `Inference` with $a \in$ `source`, $b \in$ `target`, and `against=false`, or (b) there exists a $c_1..c_n$ (for $n \geq 1$) such that $supports(a,c_1) \wedge supports(c_i,c_{i+1}) \wedge \ldots \wedge supports(c_n,b)$.
5. Concrete, specific evidence references must identify specific, real `Artifact` objects or `Argument` objects for support. That is, if an `EvidenceReference` is not `toBeSupported` and has a non-empty `reference`, its `reference` must match the `id` of an `Artifact` or `Argument`.
6. Artifact relationships must be well-specified. That is, an `ArtifactRelationship` object's `source` and `target` sets must not be empty.
7. All patterns must be fully instantiated. That is:
   (a) The `SAAIF.IsPattern` annotation may only be attached to `Argument` and `Glossary` objects.
   (b) No `ModelElement` may have an annotation with a `key` matching `SAAIF.InstantiationNote` unless one of the following is true:
      i. The `ModelElement` is a `Glossary` and it is also annotated with `SAAIF.IsPattern` $= \{$`true`$\}$.
      ii. The `ModelElement` is a `Definition` and its `Glossary` is also annotated with `SAAIF.IsPattern` $= \{$`true`$\}$.

iii. The `ModelElement` is an `Argument` and it is also annotated with `SAAIF.IsPattern` = {`true`}.
iv. The `ModelElement` is an `ArgumentElement` and its `Argument` is also annotated with `SAAIF.IsPattern` = {`true`}.

8. The `value` fields of `KeyValuePair` objects with pre-defined `keys` should have the correct types. That is:

   (a) The `value` field of any `KeyValuePair` with a `key` matching `SAAIF.InstantiationNote` must not contain nothing other than `EscapeStringValue` objects.
   (b) The `value` field of any `KeyValuePair` with a `key` matching `SAAIF.IsPattern` must contain exactly one `BooleanValue`.
   (c) The `value` field of any `KeyValuePair` with a `key` matching `SAAIF.Note` must not contain nothing other than `EscapeStringValue` objects.

If an `AssuranceCase` object's `extension` set includes an `Identifier` matching `SAAIF.Strict`, it should also meet the following goals where practicable:

1. Define terms of art clearly. In addition to avoiding circular definitions, writers should (a) avoid defining words in terms of words the reader is even less likely to understand, (b) refrain from using non-predictive constructions such as defining terms using examples or using hedges such as 'usually' or 'generally' [20].
2. Avoid the use of loaded language [21]. That is, writers should not use defined terms in such a way that knowledge of their plain-language meaning is likely to mislead readers.
3. Where practical[2], an argument's references to propositions and artifacts should be recorded using `Inference` objects and `EvidenceReference` objects rather than through the `EscapedString` mechanism.

4 Encoding

The SAAIF model presented in Section 2 might be encoded in stream or file formats not specified in this document. For the purpose of facilitating interchange, we define one standard encoding, `SAAIF_TEXT`. This encoding is defined in Appendix E.

[2] There are some instances where it might be desirable to use an `EscapedString` reference rather than an `Inference` or `EvidenceReference`. For example, one might use a `Note` to observe that one `Claim` is analogous to another `Claim` in the same argument or in another argument.

References

1. Defence Standard 00-56, Issue 6: *Safety Management Requirements for Defence Systems — Part 1: Requirements and Guidance*. (U.K.) Ministry of Defence, Glasgow, UK, Apr. 2015.

2. Holloway, C. M.: Safety Case Notations: Alternatives for the Non-Graphically Inclined? *Proceedings of the 3rd IET International Conference on System Safety (ICSS)*, Birmingham, UK, Oct. 2008.

3. Kelly, T. P.: Arguing Safety — A Systematic Approach to Managing Safety Cases. Ph.D. Thesis, University of York, York, UK, Sept. 1998. URL `http://www-users.cs.york.ac.uk/~tpk/tpkthesis.pdf`.

4. Adelard: ASCAD: Adelard Safety Case Development Manual. Electonic document, London, UK, 1988.

5. Attwood, K.; et al.: *GSN Community Standard Version 1*. Origin Consulting Limited, York, UK, Nov. 2011. URL `http://www.goalstructuringnotation.info/documents/GSN_Standard.pdf`.

6. Rushby, J.; Xidong, X.; Murali, R.; and Weaver, T. L.: Understanding and Evaluating Assurance Cases. Contractor Report NASA/CR-2015-218802, National Aeronautics and Space Administration, Hampton, VA, USA, Sept. 2015. URL `https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160000772.pdf`.

7. Haley, C. B.; Moffett, J. D.; Laney, R.; and Nuseibeh, B.: Arguing security: Validating security requirements using structured argumentation. *Proceedings of the Third Symposium on Requirements Engineering for Information Security (SREIS'05) held in conjunction with the 13th International Requirements Engineering Conference (RE'05)*, Paris, France, Aug. 2005. URL `http://oro.open.ac.uk/2488/1/`.

8. Graydon, P. J.: Formal Assurance Arguments: A Solution In Search of a Problem? *Proceedings of the 45th Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN)*, Rio de Janeiro, Brasil, June 2015. URL `http://hdl.handle.net/2060/20160006364`.

9. Toulmin, S. E.: *The Uses of Argument*. Cambridge University Press, New York, NY, USA, updated ed., 2003.

10. Schum, D. A.: *The Evidential Foundations of Probabilistic Reasoning*. Wiley, New York, NY, USA, 1994.

11. Modgil, S.; and Prakken, H.: The ASPIC+ Framework for Structured Argumentation: A Tutorial. *Argument & Computation*, vol. 5, no. 1, 2014, pp. 31–62. URL `http://www.cs.uu.nl/groups/IS/archive/henry/ASPICtutorial.pdf`.

12. OMG: *Structured Assurance Case Metamodel (SACM), Version 1.0*. Object Management Group (OMG), Feb. 2013. URL http://www.omg.org/spec/SACM.

13. OMG: *Structured Assurance Case Metamodel (SACM), Version 2.0, Beta 1*. Object Management Group (OMG), July 2016. URL http://www.omg.org/spec/SACM/2.0/Beta1/.

14. OMG: *Structured Assurance Case Metamodel (SACM), Version 2.0*. Object Management Group (OMG), Mar. 2018. URL http://www.omg.org/spec/SACM/2.0/PDF.

15. Graydon, P. J.: The Many Conflicting Visions of 'Safety Case'. *Proceedings of the IEEE/IFIP International Conference on Dependable Systems and Networks (DSN)*, 2017. Fast abstract.

16. Office for Nuclear Regulation: Safety Assessment Principles for Nuclear Facilities. , Health and Safety Executive, Bootle, UK, Nov. 2014. URL http://www.onr.org.uk/saps/saps2014.pdf, 2014 Edition, Revision 0.

17. Office for Nuclear Regulation: The Purpose, Scope, and Content of Safety Cases. ONR Nuclear Safety Technical Assessment Guide NS-TAST-GD-051 Revision 4, Health and Safety Executive, July 2016. URL http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-051.pdf.

18. Graydon, P. J.; and Holloway, C. M.: An Investigation of Proposed Techniques for Quantifying Confidence in Assurance Arguments. *Safety Science*, vol. 92, Feb. 2017, pp. 53–65.

19. Graydon, P. J.; and Holloway, C. M.: "Evidence" Under a Magnifying Glass: Thoughts on Safety Argument Epistemology. *Proceedings of the IET System Safety and Cyber Security Conference*, Bristol, UK, Oct. 2015, pp. 6–11. URL http://www.researchgate.net/publication/280247123_Evidence_Under_a_Magnifying_Glass_Thoughts_on_Safety_Argument_Epistemology.

20. Wasson, K. S.: CLEAR Requirements: Improving Validity Using Cognitive Linguistic Elicitation and Representation. Ph.D. Thesis, University of Virginia, Charlottesville, VA, USA, May 2006. URL http://www.cs.virginia.edu/~ksh4q/pubs/KWassonDissertationSingleSpaced.pdf.

21. Graydon, P. J.: Towards a Clearer Understanding of Context and Its Role in Assurance Argument Confidence. *Proceedings of the International Conference on Computer Safety, Reliability and Security (SAFECOMP)*, Springer, Florence, Italy, Sept. 2014, pp. 139–154. URL http://dx.doi.org/10.1007/978-3-319-10506-2_10.

22. Goodenough, J. B.; Weinstock, C. B.; and Klein, A. Z.: Eliminative Argumentation: A Basis for Arguing Confidence in System Properties. Technical Report CMU/SEI-2015-TR-005, Software Engineering Institute, Pittsburgh, PA, USA, Feb. 2015. URL http://resources.sei.cmu.edu/asset_files/TechnicalReport/2015_005_001_434813.pdf.

23. Holloway, C. M.: Explicate '78: Uncovering the Implicit Assurance Case in DO-178C. *Engineering Systems for Safety: Proceedings of the 23rd Safety-Critical Systems Symposium (SSS)*, M. Parsons and T. Anderson, eds., Bristol, UK, Feb. 2015. URL http://www.cs.virginia.edu/~cmh7p/e78sss2015.pdf.

24. Holloway, C. M.; and Graydon, P. J.: Explicate '78: Assurance Case Applicability to Digital Systems. Final report, Federal Aviation Administration, Dec. 2016. In Press.

25. Aiello, M. A.; Hocking, A. B.; Knight, J.; and Rowanhill, J.: SCT: A Safety Case Toolkit. *Proceedings of the 2nd International Workshop on Assurance Cases for Software-Intensive Systems (ASSURE)*, 2014, pp. 216–219.

Appendix A

Mapping to the Goal Structuring Notation

The Goal Structuring Notation (GSN) is a popular graphical notation for recording assurance arguments [5]. While it is not possible to convert arguments between SAAIF and GSN without some loss of information or refactoring, it is useful for pedagogical purposes to explain which concepts in GSN align with which concepts in the SAAIF and vice-versa. Table A1 sketches such a mapping.

Table A1: *Mapping between the GSN and the SAAIF.*

GSN Goal	**SAAIF** `Claim`	**Note** `Claim` supported by `Inference`s.
Strategy	`description` of `Inference`	
Solution	`Evidence-Reference`	
Context (as definition [21])	`Definition`	Definitions apply case-wide.
Context (as background)	`Claim` in the `background` of an `Argument`	
Context (as artifact)	?	Depends on the purpose of asserting the artifact [21].
Justification as context for strategy	`Inference` from `Claim` to `Inference`	The `Claim` gives the justification text; the `target Inference` represents the strategy.
Assumption	`Claim`	`Claim` *without* support.
Undeveloped entity	`toBeSupported`	
SupportedBy	`Inference`	Except that the goal-supported-by-strategy-supported-by-goal construct is represented as a described `Inference` from the first `Claim` to the second.
InContextOf	No direct equivalent	See mappings for Context and Away Goals.
Uninstantiated entity	`toBeModified`	
Number/choice decorations	`Instantiation-Note`	(See Section 2.4.)

Table A1: *Mapping between the GSN and the SAAIF (continued).*

GSN	SAAIF	Note
Bracketed text	`Definition` in `Glossary` that `IsPattern`	Placeholder text in patterns can refer to associated definitions.
Away goal	`Inference` from other `Argument` to `Claim`	Claims in other arguments can't be referenced directly; the reader must determine whether and how the referenced `Argument` supports the `Claim`.
Module reference	`Evidence-Reference` to `Argument`	
Away solution	`Evidence-Reference` to same `Artifact`	
Away context	No direct equivalent	Can be duplicated depending on how the context is being used.
Public entity	No direct equivalent	A `Claim` in one `Argument` cannot be directly referenced from another `Argument`.

Appendix B

Mapping to Toulmin's model

Toulmin's classic text defines a model for informal argumentation that is still used as a model today [9]. Figure B1 depicts Toulmin's model. While it is not possible to convert arguments between SAAIF and Toulmin's model without some loss of information or refactoring, it is useful for pedagogical purposes to explain which concepts in Toulmin's model align with which concepts in the SAAIF and vice-versa. Table B1 sketches such a mapping.

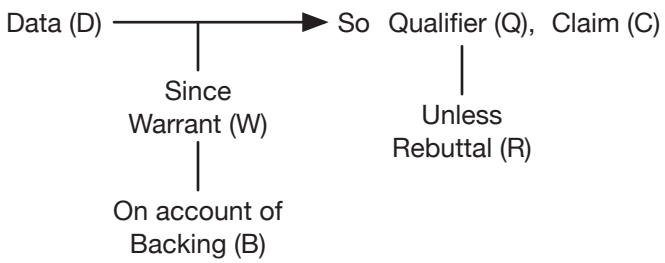


Figure B1: *Toulmin's model of informal argumentation.*

Table B1: *Mapping between Toulmin's model and the SAAIF.*

Toulmin's model	**SAAIF**
Data	`Claim` or `EvidenceReference`
Warrant	`Inference` from `Claim` to `Inference`
Backing	`Inference` to the `Claim` presenting the warrant
Qualifier	Text in the `description`
Rebuttal	`Inference` with `against=true` to the `Claim`
Claim	`Claim`

Appendix C

Mapping to Confidence Maps

Some argument notations, including the Goal Structuring Notation (GSN), lack an explicit mechanism for presenting *counterevidence* [5]. To address this lack, Goodenough et al. propose *eliminative argumentation* in the form of *confidence maps* [22]. Figure C1 depicts a confidence map, which introduces to familiar GSN symbols representing *inference rules*, the *rebutting*, *undercutting*, and *undermining defeaters* familiar to students of informal argumentation, and the writer's assertion that something is either deductively *OK* or *assumed OK*. Table C1 sketches a mapping from confidence maps to the SAAIF.

Table C1: *Mapping between confidence maps and the SAAIF.*

Confidence map	**SAAIF**
Inference rule	`Inference` from `Claim` (expressing the rule) to `Inference`
Rebutting defeater	`Inference` with `against=true` from `Claim` expressing the reason to `Claim` expressing the rebutted claim.
Undercutting defeater	`Inference` with `against=true` from `Claim` expressing the reason to the rebutted `Inference`.
Undermining defeater	Either (1) an `Inference` with `against=true` from `Claim` expressing the reason to the rebutted `EvidenceReference` or (2) an `Inference` with `against=true` from `Claim` expressing the reason to the `Inference` from the rebutted evidence.
Assumed/is OK	No direct equivalent. A writer might mark an `ArgumentElement` as `toBeSupported` to indicate that it should be revisited. Readers may use their own annotations to record their acceptance of or confidence in claims, evidence references, and inferences.

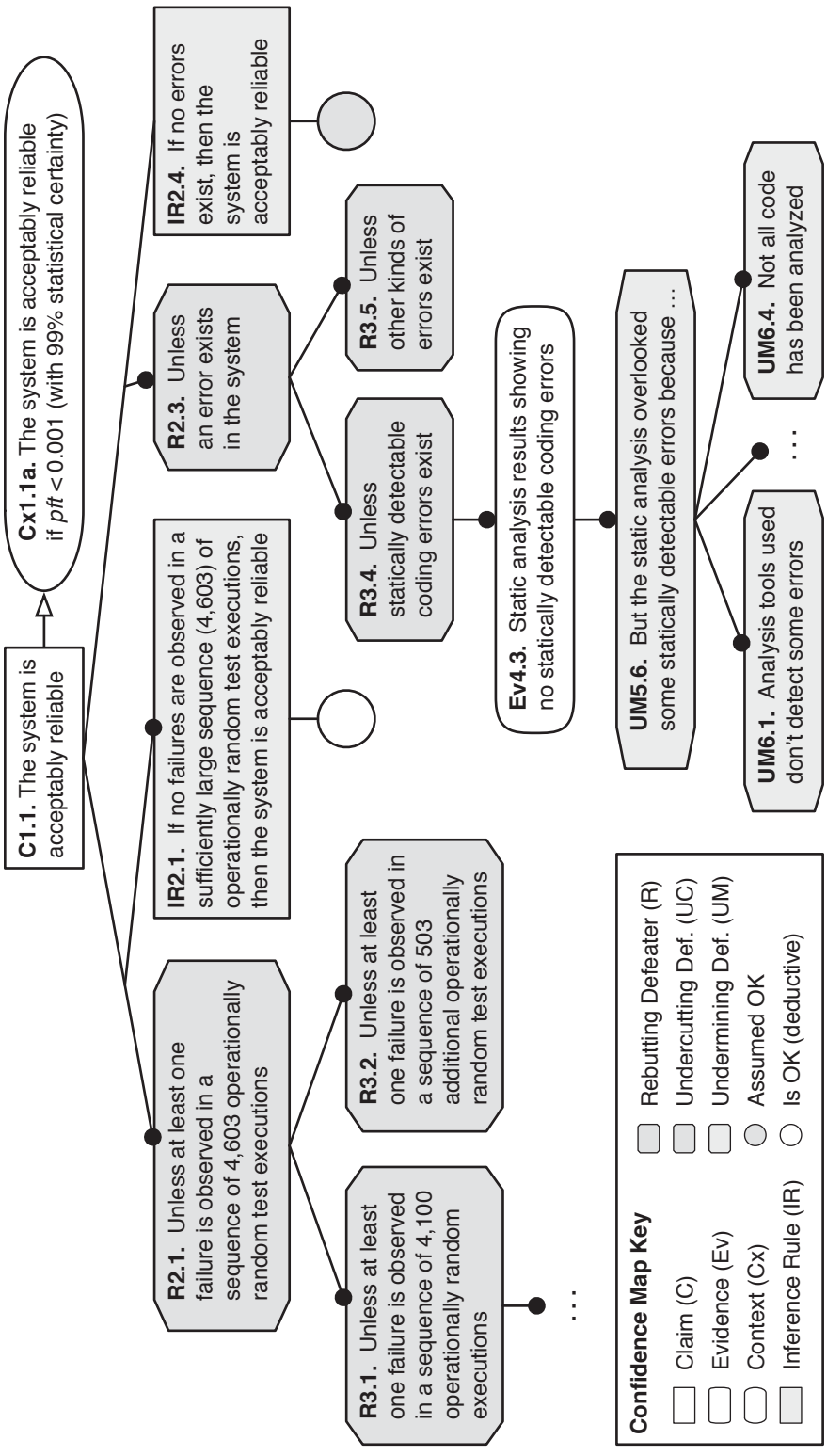


Figure C1: *Example "multi-legged confidence map" adapted from [22].*

Appendix D

Example: Explicate ’78 revisited

Researchers have developed an assurance case representing the logic of RTCA’s DO-178C standard for airborne software [23, 24]. In this section, we present a re-imagining of part of that argument in SAAIF as an example of how SAAIF might be used.

Figure D1 reproduces Figure 3 (“Level D primary argument in GSN”) from a paper reporting a draft of that argument [23]. The figure is presented in a variant of the Goal Structuring Notation used by a specific argument editing tool [5, 25]. The argument is not a traditional safety argument, but rather an attempt to capture a standard’s logic, and so it differs from traditional software safety arguments in, e.g., referring to requirements and evidence in the abstract.

Figures D2–D4 give the argument as modeled using the SAAIF. Because SAAIF does not have a canonical graphical form, we illustrate the SAAIF model using a UML instance diagram. While this graphical form is somewhat bulky and impenetrable, we use it here to directly illustrate how the SAAIF’s fields and relationships might be used in modeling.

Figures D2–D4 are not a direct translation of Figure D1. Several differences are worthy of special mention:

- The GSN argument uses context elements to define terms of art. The SAAIF argument uses explicitly modeled definitions instead (permitting a user agent to render the defined terms as, e.g., hyperlinks).
- The GSN argument records as contextual information the assertion that “the software has been assigned to level D.” The SAAIF argument instead records this as a background assumption. If this assumption is not true, the argument becomes irrelevant.
- The (modified) GSN argument uses an assurance claim point (rendered as a box decorating the strategy) to link to a confidence argument (not shown). The SAAIF argument instead introduces the confidence claim as background supported by the confidence argument. This background knowledge should shape the reader’s interpretation of this argument, including the strength of inferences from evidence.
- The GSN argument renders objectives requiring the development of artifacts such as the high-level requirements as contextual information. The SAAIF argument records these objectives instead as inferences to the argument’s main inference. If high-level requirements do not exist, the main inference makes no sense.

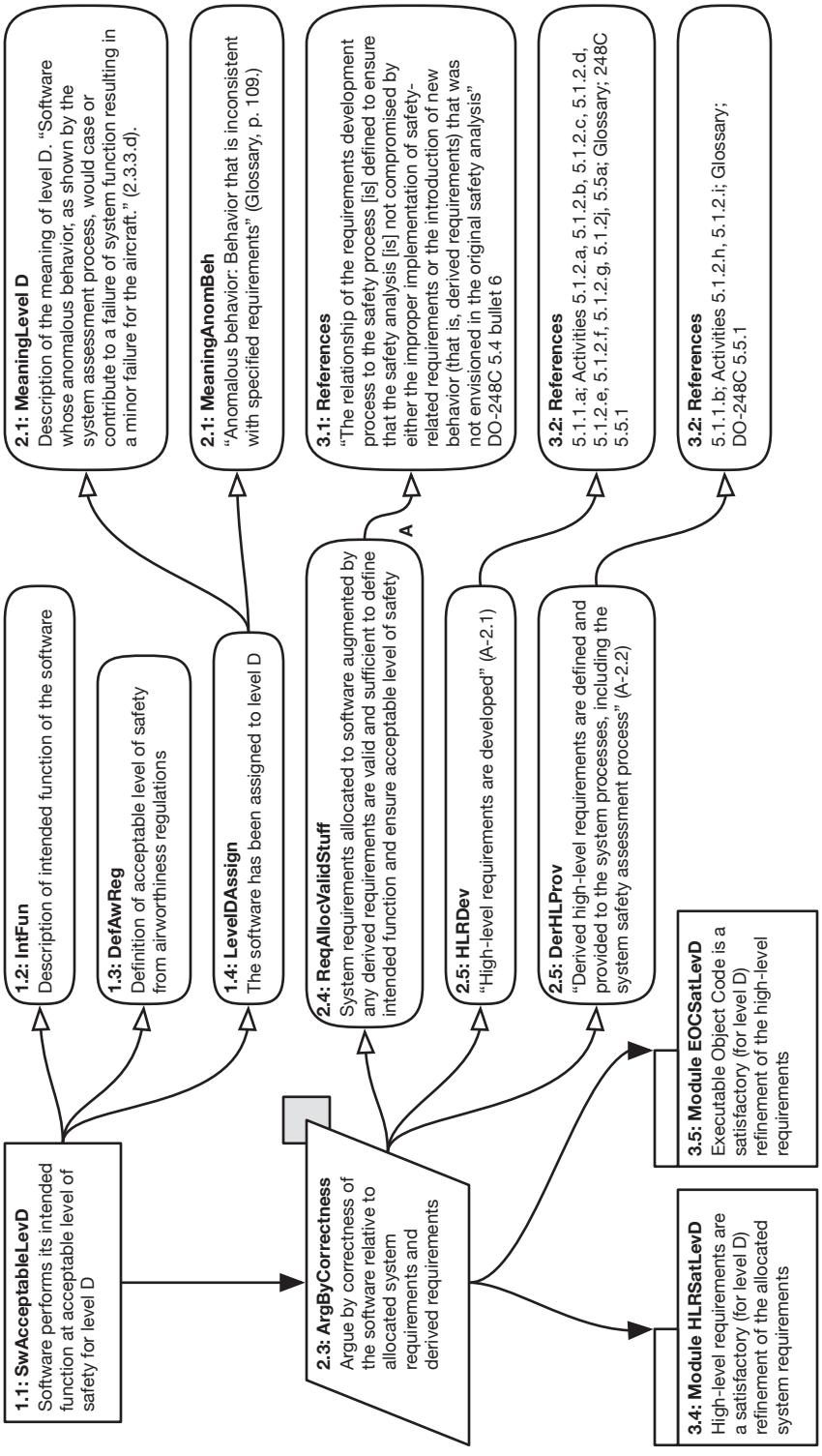


Figure D1: *Reproduction of "Level D primary argument" from [23] in modified GSN.*

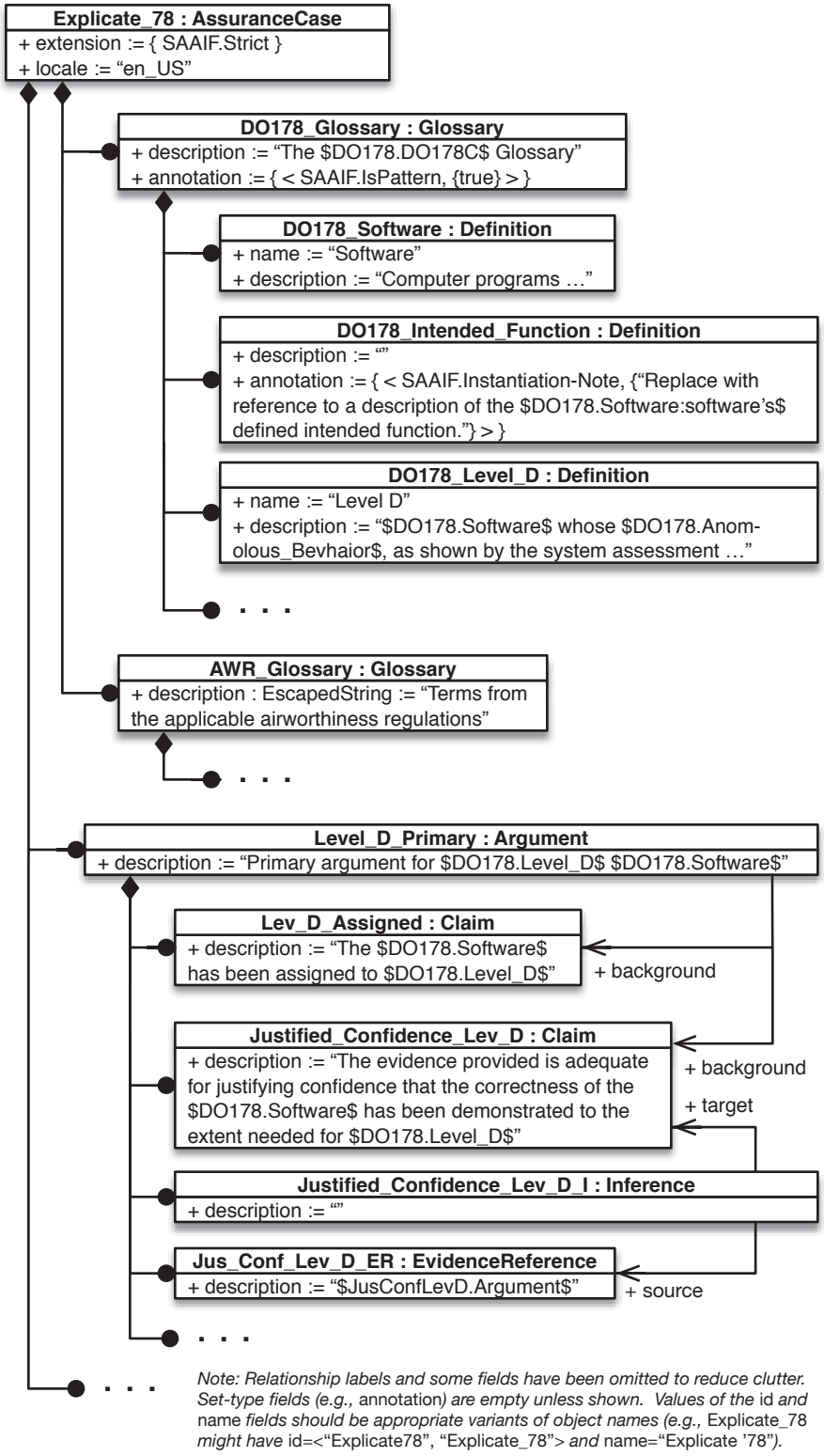


Figure D2: *Adaptation of "Level D primary argument" from [23] (part 1 of 3).*

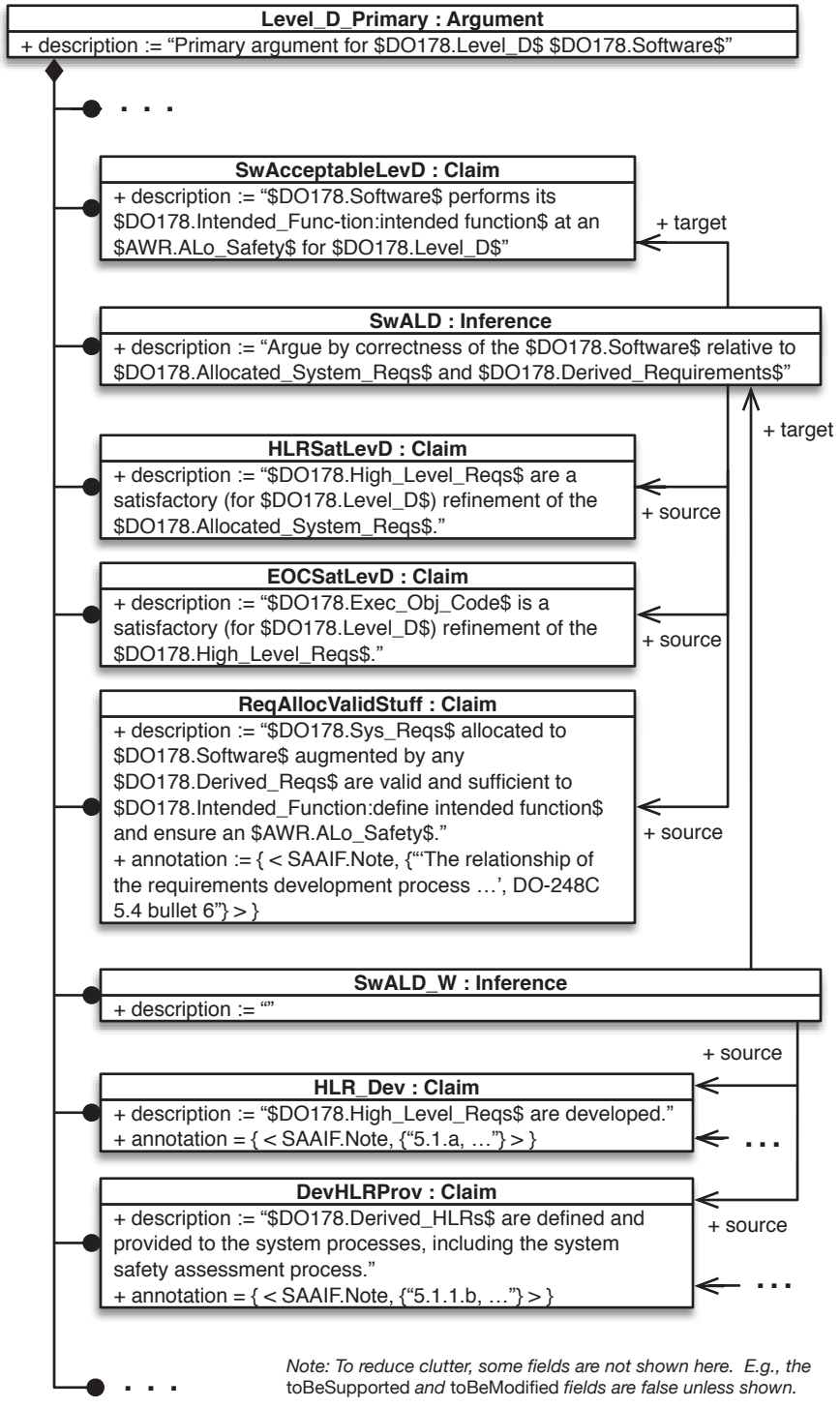
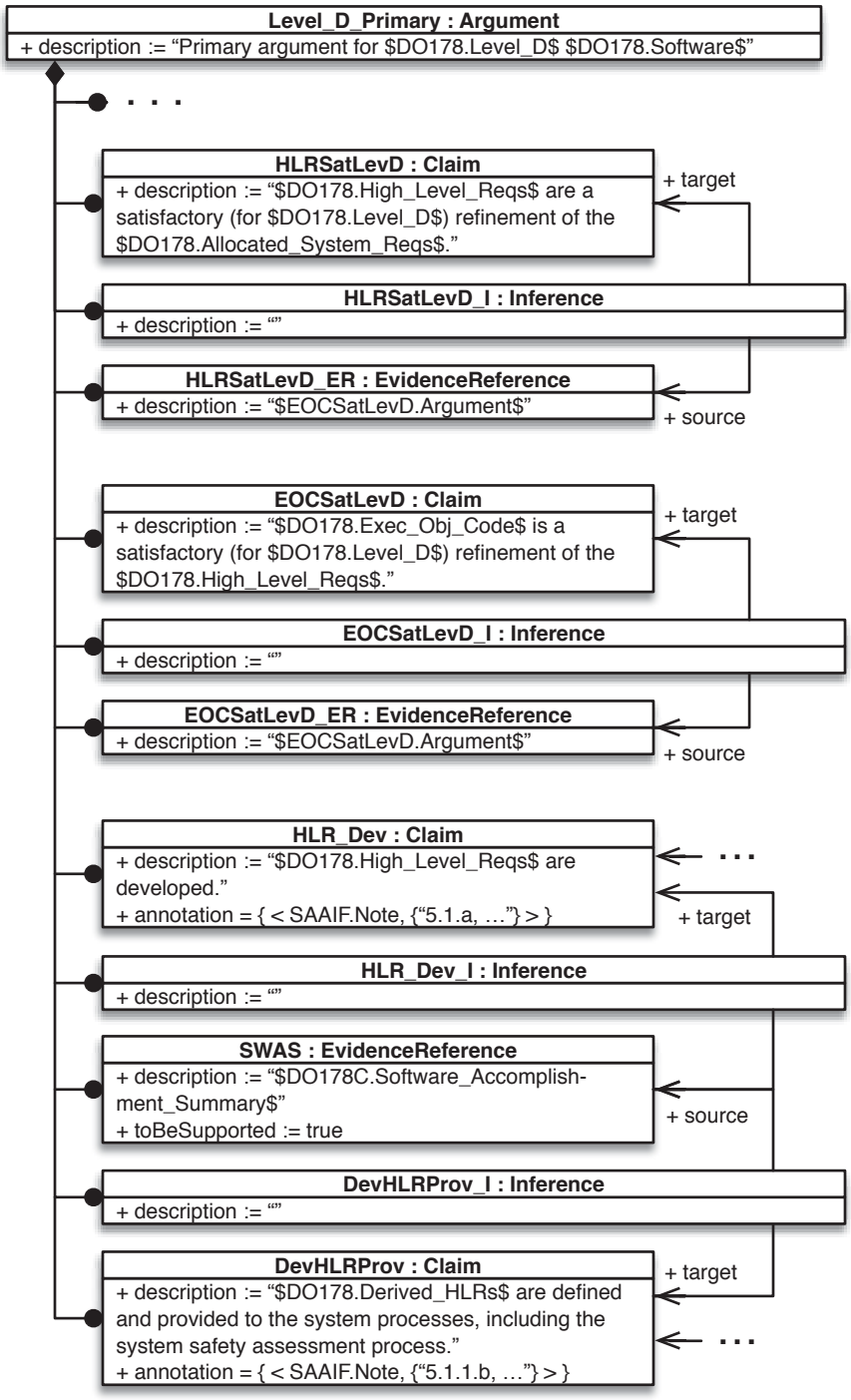


Figure D3: *Adaptation of “Level D primary argument” from [23] (part 2 of 3).*



Note: Claims HLR_Dev and DevHLRProv were originally rendered as context. Here, we render them as evidence to show how reference as-yet-undeveloped evidence. Their appearance in two figures is meant only to permit splitting the argument over several pages; they would not be duplicated.

Figure D4: *Adaptation of “Level D primary argument” from [23] (part 3 of 3).*

Appendix E

Text-based encoding `SAAIF_TEXT`

It is useful to have at least one canonical file or stream format for encoding SAAIF arguments. This section presents a text file encoding, `SAAIF_TEXT`.

E.1 Character encoding

The characters that comprise a `SAAIF_TEXT` file shall be encoded in UTF-8.

E.2 Lexical structure

A `SAAIF_TEXT` file comprises the following tokens:

Bareword. A sequence of one or more characters from the same set that `Identifier`s comprise, namely {'`a`', ..., '`z`', '`A`', ..., '`Z`', '`0`', ..., '`9`', '`_`'}.

Identifier. An identifier comprises two parts separated by a period ('`.`'). Each part might be either a `bareword` or an asterisk ('`*`'). The first part is the `domain` field. The second part is the `name` field. An asterisk represents an empty field.

UID. A sequence of 1–16 uppercase or lowercase hexidecimal digits. `UID`s need not be truly unique. (See Section E.4 for details.)

Symbol. Symbols—operators and punctuation—include '=', '`;`', '`{`', '`}`', '`,`', and '+'.

String literal. A string literal begins with a double-quote character ('`"`'), contains any characters other than a newline or an unescaped double-quote, and ends with a double-quote. Escape sequences begin with a pipe character ('`|`'):

- '`||`' represents a single pipe character.
- '`|"`' represents a double-quote character.
- '`|n`' represents a newline character.
- '`|`' followed by one or more hexadecimal digits represents the unicode code point with the given value.

Escaped string literal. A backslash character ('`\`') followed immediately by what would otherwise be a `string literal`.

Comment. A comment is a pair of hyphen characters ("`--`") followed by all non-newline characters up to the next newline.

Whitespace. The whitespace characters are space, horizontal tab, newline, and carriage-return appearing outside of a `string literal` or `escaped string literal`. Whitespace is ignored.

E.3 Grammar

We present the SAAIF_TEXT grammar in Backus–Naur Form (BNF) notation with regular expression extensions. Words appearing in all upper case are nonterminal names. SAAIF_TEXT_FILE represents a complete file. Words appearing in all lower case are token names. Token literals appear in quotes and are not case sensitive. IMPORT_STATEMENTs should be treated as though they were replaced by the contents of the file whose path is given by the string literal. A single VALUE appearing in a PARAMETER is interpreted identically to a VALUE_SET with that single value.

```
SAAIF_TEXT_FILE := ASSURANCE_CASE*;
ASSURANCE_CASE := 'AssuranceCase' identifier
    'is' PARAMETER+ 'begin' AC_CONTENT* 'end' ';';
AC_CONTENT := IMPORT_STATEMENT | GLOSSARY |
    INVENTORY | ARGUMENT;

PARAMETER := (bareword | identifier) '='
    (VALUE | VALUE_SET) ';';
VALUE_SET := '{' (VALUE (',' VALUE)*)? '}';
VALUE := STRING | ESC_STRING | BOOLEAN |
    identifier | uid;
STRING := string ('+' string)*;
ESC_STRING := escaped_string
    ('+' escaped_string)*;
BOOLEAN := 'true' | 'false';

IMPORT_STATEMENT := 'import' string ';';

GLOSSARY := 'Glossary' identifier
    'is' PARAMETER+ 'begin' DEFINITION* 'end' ';';
DEFINITION := 'Definition' identifier
    'is' PARAMETER+ 'end' ';';

INVENTORY := 'Inventory' identifier
    'is' PARAMETER+ 'begin' I_CONTENT* 'end' ';';
I_CONTENT := ARTIFACT | ARTIFACT_RELATIONSHIP;
ARTIFACT := 'Artifact' identifier uid
    'is' PARAMETER+ 'end' ';';
ARTIFACT_RELATIONSHIP := 'ArtifactRelationship'
    identifier 'is' PARAMETER+ 'end' ';';

ARGUMENT := 'Argument' identifier
    'is' PARAMETER+ 'begin' ARGUMENT_ELEMENT*
    'end' ';';
ARGUMENT_ELEMENT := CLAIM | EVIDENCE_REF |
    INFERENCE;
CLAIM := 'Claim' identifier uid
    'is' PARAMETER+ 'end' ';';
EVIDENCE_REF := 'EvidenceReference' identifier uid
    'is' PARAMETER+ 'end' ';';
```

```
INFERENCE := 'Inference' identifier uid
    'is' PARAMETER+ 'end' ';';
```

E.4 Semantics

In this section, we describe the relationship between the SAAIF_TEXT grammar and the SAAIF model.

ModelElement. Each ASSURANCE_CASE, GLOSSARY, INVENTORY, ARTIFACT, ARGUMENT, CLAIM, EVIDENCE_REF, or INFERENCE nonterminal encodes a ModelElement of the kind indicated by its initial token. The fields of a ModelElement are generally given by PARAMETER nonterminals appearing before the next "begin" token. The description and name fields of a ModelElement are given by PARAMETER nonterminals with the bareword tokens "description" and "name", respectively. Its id field is given by the identifer immediately following its initial token. Its annotation field is given by the set of PARAMETER nonterminals beginning with "identifier" tokens. Unless otherwise specified, the fields of derived classes are given by PARAMETER nonterminals with corresponding bareword tokens.

AssuranceCase. The part of each ASSURANCE_CASE nonterminal appearing between its first "begin" token and its last "end" token gives its inventory, argument, and glossary contents in the form of the GLOSSARY, INVENTORY, and ARGUMENT nonterminals that appear there.

Glossary. The part of each GLOSSARY appearing between its first "begin" token and its last "end" token gives the entry field for the Glossary it represents.

Inventory. The part of each INVENTORY appearing between its first "begin" token and its last "end" token gives the relationship and artifact fields for the Inventory.

Artifact. Each ARTIFACT in a given INVENTORY must have a unique uid.

ArtifactRelationship. The source and target fields of each ArtifactRelationship will be given as PARAMETER nonterminals with the bareword tokens "source" and "target". Those PARAMETER nonterminals will have VALUE_SET nonterminals comprising only uid tokens, each giving the uid of an ARTIFACT in the same INVENTORY.

Argument. The part of each ARGUMENT appearing between its first "begin" token and its last "end" token gives the content field for the argumentArgument it represents. The Argument's background field will be represented by a PARAMETER with the bareword "background" and a VALUE_SET comprising only uids, each of which identifies an ARG_CONTENT in the same ARGUMENT.

ArgumentElement. Each `ARGUMENT_ELEMENT` in a given `Argument` must have a unique `uid`.

Inference. The `source` and `target` fields of each `Inference` will be given as `PARAMETER` nonterminals with the `bareword` tokens "`source`" and "`target`". Those `PARAMETER` nontermainls will have `VALUE_SET` nonterminals comprising only `uid` tokens, each giving the `uid` of an `ARGUMENT_ELEMENT` in the same `ARGUMENT`.

E.5 Example

The following example illustrates how one might encode the argument fragment depicted in Figure D2.

```
AssuranceCase Explicate_78.Explicate_78 is
  extension = { SAAIF.Strict };
  locale = "en_US";
  name = "Explicate '78";
begin
  Glossary DO1788.Glossary is
    description = \"The $DO178.DO178C$ Glossary";
    name = "DO178 Glossary";
    SAAIF.IsPattern = true;
  begin

    Definition DO178.Software is
      description = \"Computer programs ...";
      name = "Software";
    end;

    Definition DO178.Intended_Function is
      description = \"";
      name = "Indended Function";
      SAAIF.InstantiationNote = { \"Replace with " +
        \"a reference to a description of the " +
        \"$DO178.Software:software's$ defined " +
        \"intended function." };
    end;

    Definition DO178.Level_D is
      description = \"$DO178.Software$ whose " +
        \"$DO1789.Anomolous_Behavior$, as shown " +
        \"by the system assessment ...";
      name = "Level D";
    end;

    --  Some definitions elided
  end;
```

```
  Glossary AWR.Glossary is
    description = \"Terms from the applicable " +
      \"airworthiness regulations.";
    name = \"AWR Glossary";
  begin
    --  Definitions elided
  end;

  Argument Level_D_Primary.Argument is
    description = \"Primary argument for " +
      \"$DO178.Level_D$ $DO178.Software$";
    name = "Level D Primary";
    background = { 1, 2 };
  begin
    Claim Level_D_Primary.Lev_D_Assigned 1 is
      description = \"The $DO178.Software$ has " +
        \"been assigned to $DO178.Level_D$.";
      name = "Lev D Assigned";
    end;

    Claim
      Level_D_Primary.Justified_Confidence_Lev_D
      2 is
      description = \"The evidence provided is " +
        \"adequate for justifying confidence " +
        \"that the correctness of the $DO178." +
        \"Software$ has been demonstrated to " +
        \"the extent needed for $DO178.Level_D$.";
      name = "Justified Confidence Lev D";
    end;

    Inference
      Level_D_Primary.Justified_Confidence_Lev_D_I
      3 is
      description = \"";
      name = "Justified Confidence Lev D I";
      source = { 4 };
      target = { 2 };
    end;

    EvidenceReference
      Level_D_Primary.Jus_Conf_Lev_D_ER 4 is
      description = \"$JusConfLevD.Argument";
      name = "Jus Conf Lev D ER";
    end;

    --  Some argument elements elided
  end;

  --  Some assurance case elements elided
end;
```

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14. ABSTRACT
This document describes the Simple Assurance Argument Interchange Format, a proposed meta-model for describing structured assurance arguments. We describe the syntax and semantics of the model elements, compare the meta-model to existing argument formats, and give an example to illustrate its use.

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