Structuring and potentially formalising (Assurance) Case Arguments

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Overview

- Safety Cases and Safety Arguments
- Structured (but Informal) Arguments
- Considerations in Formalisation
- Structured Assurance Case Metamodel (SACM)

Safety Cases

- The purpose of a safety case can be defined in the following terms:

A safety case should communicate a clear, comprehensive and defensible argument (supported by evidence) that a system is acceptably safe to operate in a particular context

- Communication is an important aspect

Synthesis of Evidence

- (Dynamic) Test Results
- Analysis
- In-Service Fault Data
- CVs
- Procedures
- Human Reviews
- Failure Modes and Effects Analysis
- Timing Analysis
- Static Code Analysis
- Hardware – software testing
- Simulation results …

Software System Examples

Three types of argument

- (Causal) Behavioural arguments of **risk** management, i.e. how the causes of hazards are eliminated or mitigated, or how the consequences of hazards are mitigated.

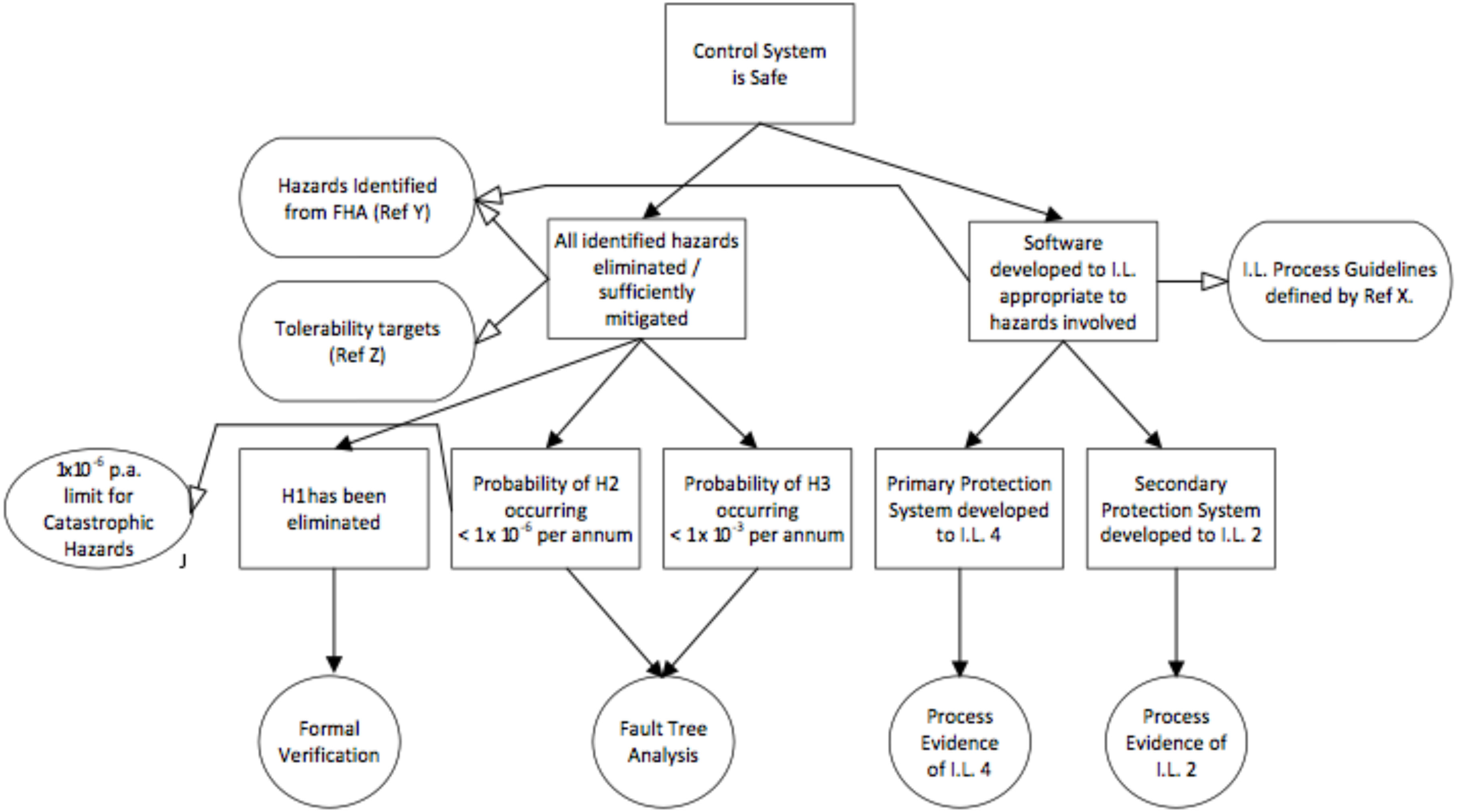
- Confidence arguments – arguments that provide confidence in the adequacy of the details of the risk management argument, e.g. justifying the adequacy of hazard identification techniques, or the sufficiency of verification results presented.

- Arguments of conformance / compliance with safety standards, regulations, and legislation – where compliance is not straightforward it is necessary to justify how a project, system design and operation have addressed legal and regulatory obligations.

Arguments

- Historically, narrative text commonly used
  - Shared understanding?
- Structured Argumentation Approaches
  - GSN - Goal Structuring Notation, CAE etc.
  - GSN clearly disambiguates the structure and elements of the argument, it cannot ensure that the argument itself is ‘good’ or sufficient for its purpose

GSN Example



Control System is Safe
Hazards Identified from FHA (Ref Y)
All identified hazards eliminated / sufficiently mitigated
Software developed to I.L. appropriate to hazards involved
I.L. Process Guidelines defined by Ref X.
Tolerability targets (Ref Z)
1x10^{-6} p.a. limit for Catastrophic Hazards
J
H1 has been eliminated
Probability of H2 occurring < 1x 10^{-6} per annum
Probability of H3 occurring < 1x 10^{-3} per annum
Primary Protection System developed to I.L. 4
Secondary Protection System developed to I.L. 2
Formal Verification
Fault Tree Analysis
Process Evidence of I.L. 4
Process Evidence of I.L. 2

Supporting Informal Arguments

- Deductive arguments (Formal Logic)
  - if the premises are true, then the conclusion must also be true
- Inductive arguments (Informal Logic)
  - the conclusion follows from the premises not with necessity, but only with ‘probability’

Formalising the Informal

- Growing interest in how these informal safety arguments may be modelled in formal logic
- The informality of the underlying reasoning present in safety assurance cannot be eliminated
  - e.g. justification of the domain experience of personnel involved in hazard analysis
- However, the informal arguments can be represented by formal logic

Inductive -> Deductive?

- formalisation can involve axiomatising (informal) aspects of the argument at the 'edge' of our argument
  - e.g. ‘all hazards identified’ argument
  - Of course, could structure this further
    - Kicking the can down the road?
    - Further set of axioms covering the informal aspects of the formalised argument

Are all types of safety case argument equally amenable to formalisation?

- valuable service has been performed by 'annexing' the informal arguments to an easily identified location (a form of reductionism)?

- concern: illusion of formality created through hiding problematic informal and subjective arguments behind an abstraction

- formalised ‘core’ with informality pushed to the periphery of the formalisation is advantageous or dangerous for evaluation and review?

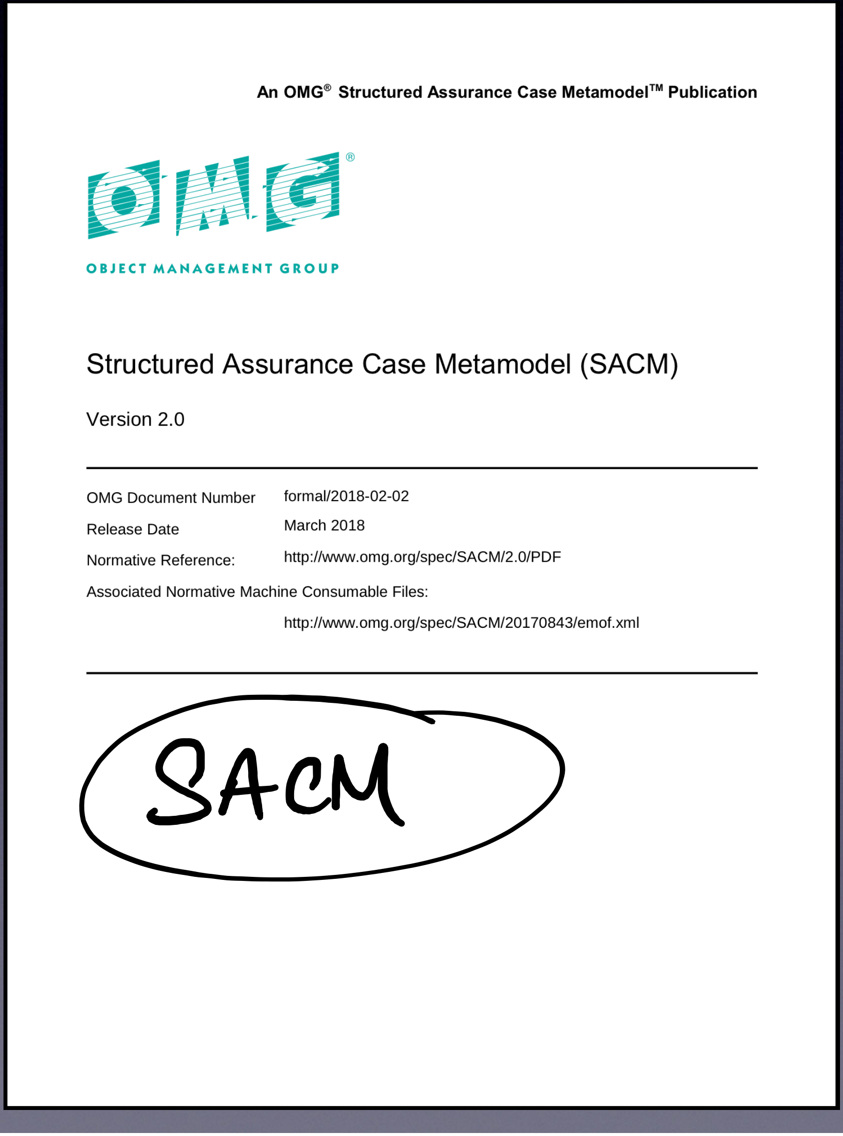
- formalisation will not reduce perhaps the most significant aspect of the review burden – namely individual review and acceptance of subjective (informal) assertion

Does the subject matter of a safety case argument affect the value of formalisation?

- deductive arguments can form part of a safety case
    - when subject matter domain is itself logical
    - asserted inferences can become provable inferences
    - When safety case arguments (or at least portions of them can become provable) are they perhaps not better represented as evidence (i.e. proof), rather than as informal logic?
- value of a safety case is to represent the informal logical ‘glue’ that pulls together different forms of the evidence (including deductive results – proof being one such example)

Supporting
Model Based Safety Cases

- Systems Assurance Task Force within the OMG (Object Management Group) has been developing a standard for the interchange ‘model’ of assurance cases for 10+ years
  - First ARM (Argumentation Metamodel) + SAEM Software Assurance Evidence Metamodel
  - Then SACM 1.0 in 2012
  - Them SACM 2.0 in 2018



An OMG® Structured Assurance Case Metamodel™ Publication

OMG

OBJECT MANAGEMENT GROUP

Structured Assurance Case Metamodel (SACM)

Version 2.0

OMG Document Number	formal/2018-02-02
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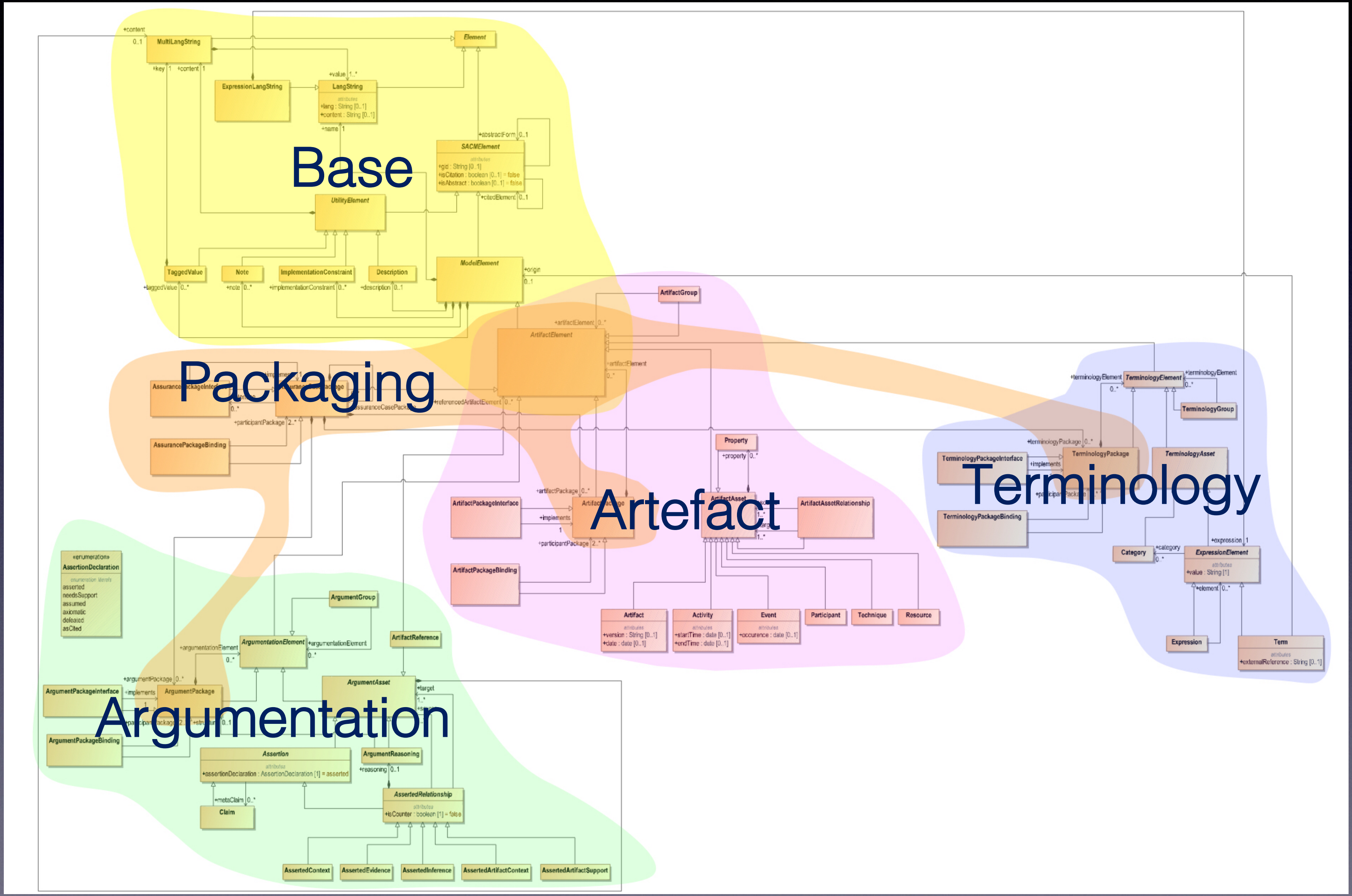
Normative Reference:	http://www.omg.org/spec/SACM/2.0/PDF

Associated Normative Machine Consumable Files:

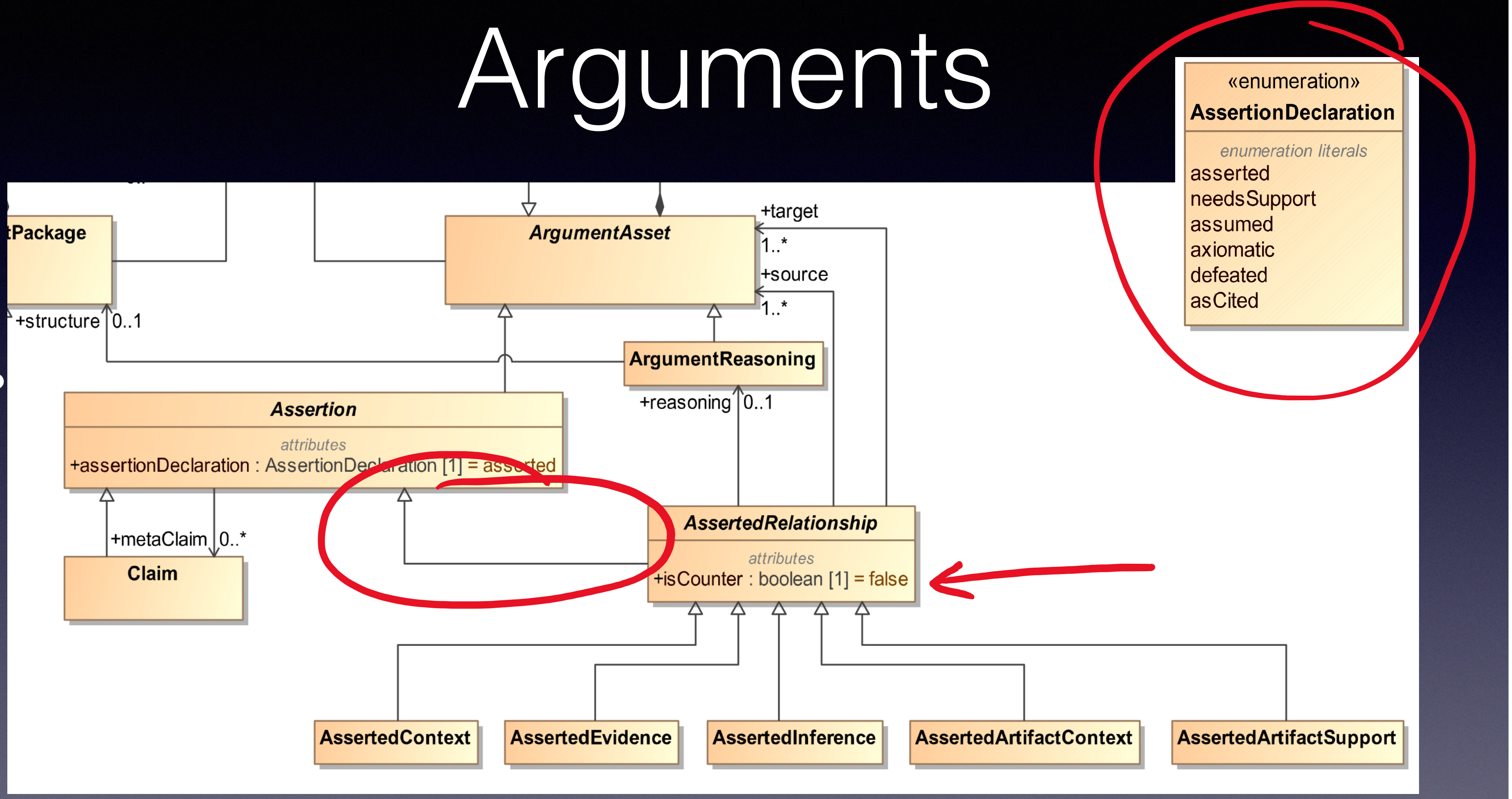
http://www.omg.org/spec/SACM/20170843/emof.xml

SACM

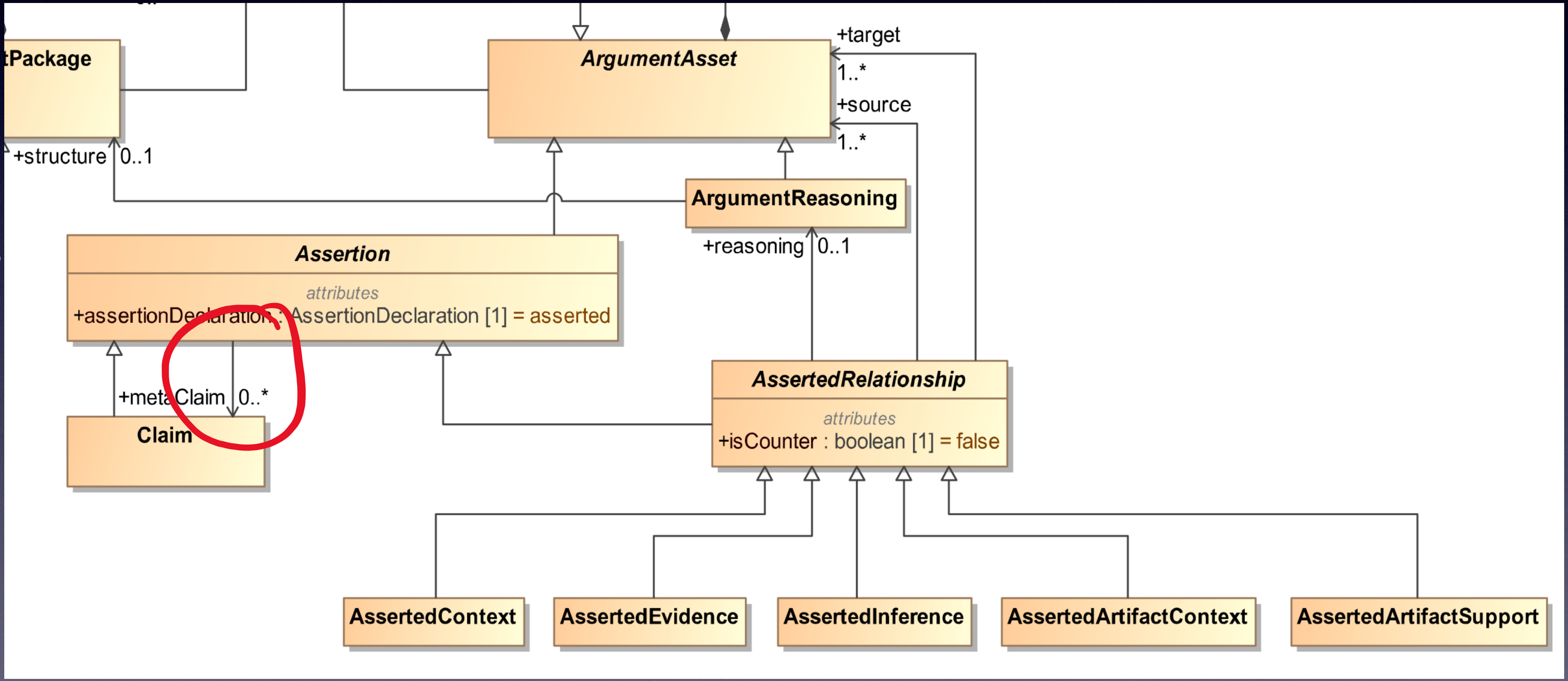
SACM 2.0


Base
Packaging
Artefact
Terminology
Argumentation
MultiLangString
Element
ExpressionLangString
LangString
attributes
+lang : String [0..1]
+content : String [0..1]
SACMElement
+gid : String [0..1]
+isCitation : boolean [0..1] = false
+isAbstract : boolean [0..1] = false
UtilityElement
TaggedValue
Note
ImplementationConstraint
Description
ModelElement
+content
+key
+value
+name
+abstractForm
+citedElement
+origin
+taggedValue
+note
+implementationConstraint
+description
AssurancePackageInterface
AssuranceCasePackage
AssurancePackageBinding
+participantPackage
+referencedArtifactElement
ArtifactGroup
ArtifactElement
+artifactElement
ArtifactPackageInterface
ArtifactPackage
ArtifactPackageBinding
+artifactPackage
+implements
Property
+property
ArtifactAsset
ArtifactAssetRelationship
Artifact
+version : String [0..1]
+date : date [0..1]
Activity
+startTime : date [0..1]
+endTime : date [0..1]
Event
+occurence : date [0..1]
Participant
Technique
Resource
TerminologyElement
+terminologyElement
TerminologyGroup
TerminologyPackageInterface
TerminologyPackage
+terminologyPackage
TerminologyAsset
TerminologyPackageBinding
Category
+category
ExpressionElement
+value : String [1]
+expression
+element
Expression
Term
+externalReference : String [0..1]
«enumeration»
AssertionDeclaration
enumeration literals
asserted
needsSupport
assumed
axiomatic
defeated
asCited
ArgumentGroup
ArgumentationElement
+argumentationElement
ArtifactReference
ArgumentPackageInterface
ArgumentPackage
+argumentPackage
ArgumentAsset
+target
ArgumentPackageBinding
Assertion
+assertionDeclaration : AssertionDeclaration [1] = asserted
ArgumentReasoning
+reasoning
+metaClaim
Claim
AssertedRelationship
+isCounter : boolean [1] = false
AssertedContext
AssertedEvidence
AssertedInference
AssertedArtifactContext
AssertedArtifactSupport

Supporting Dialectic Arguments

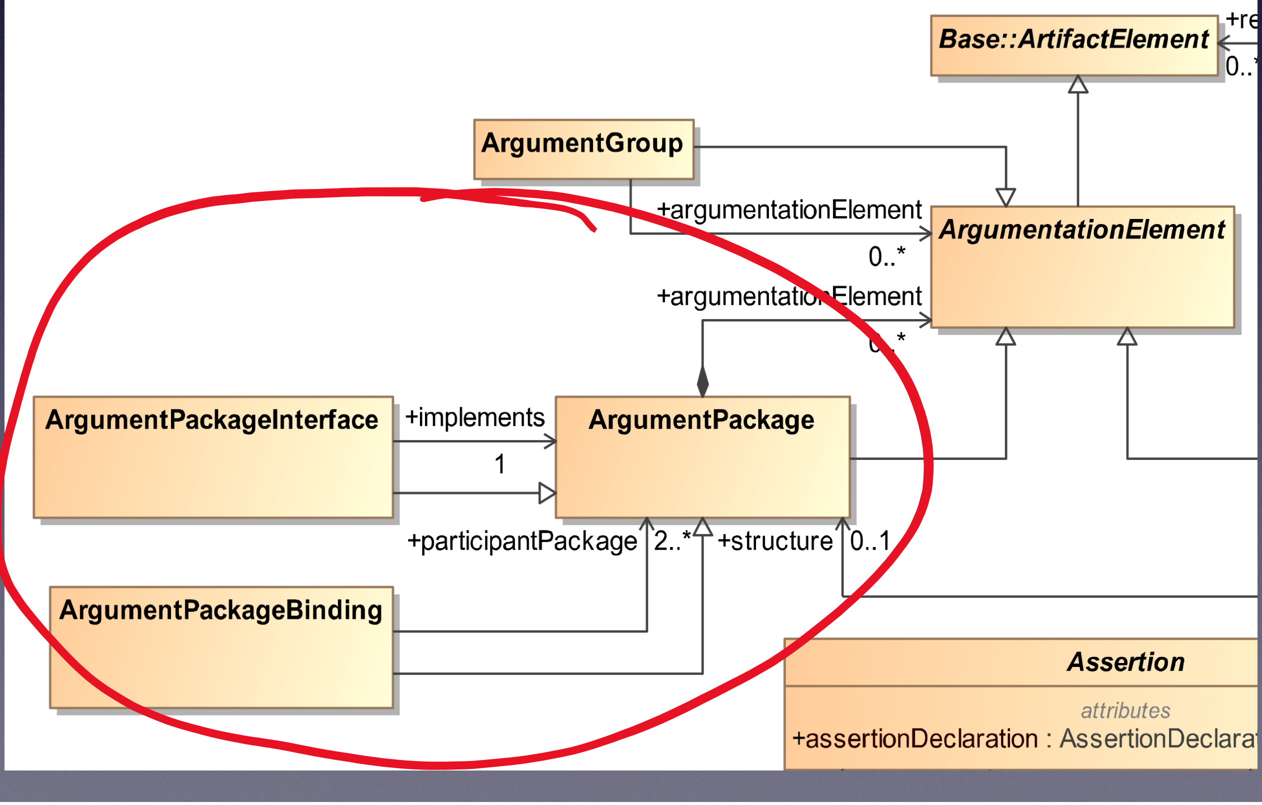


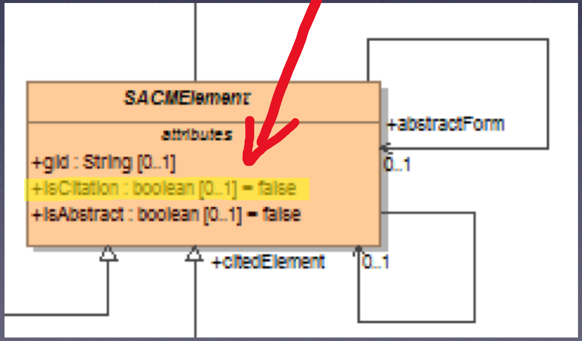
Supporting Confidence Arguments



Supporting Modularity / Packaging

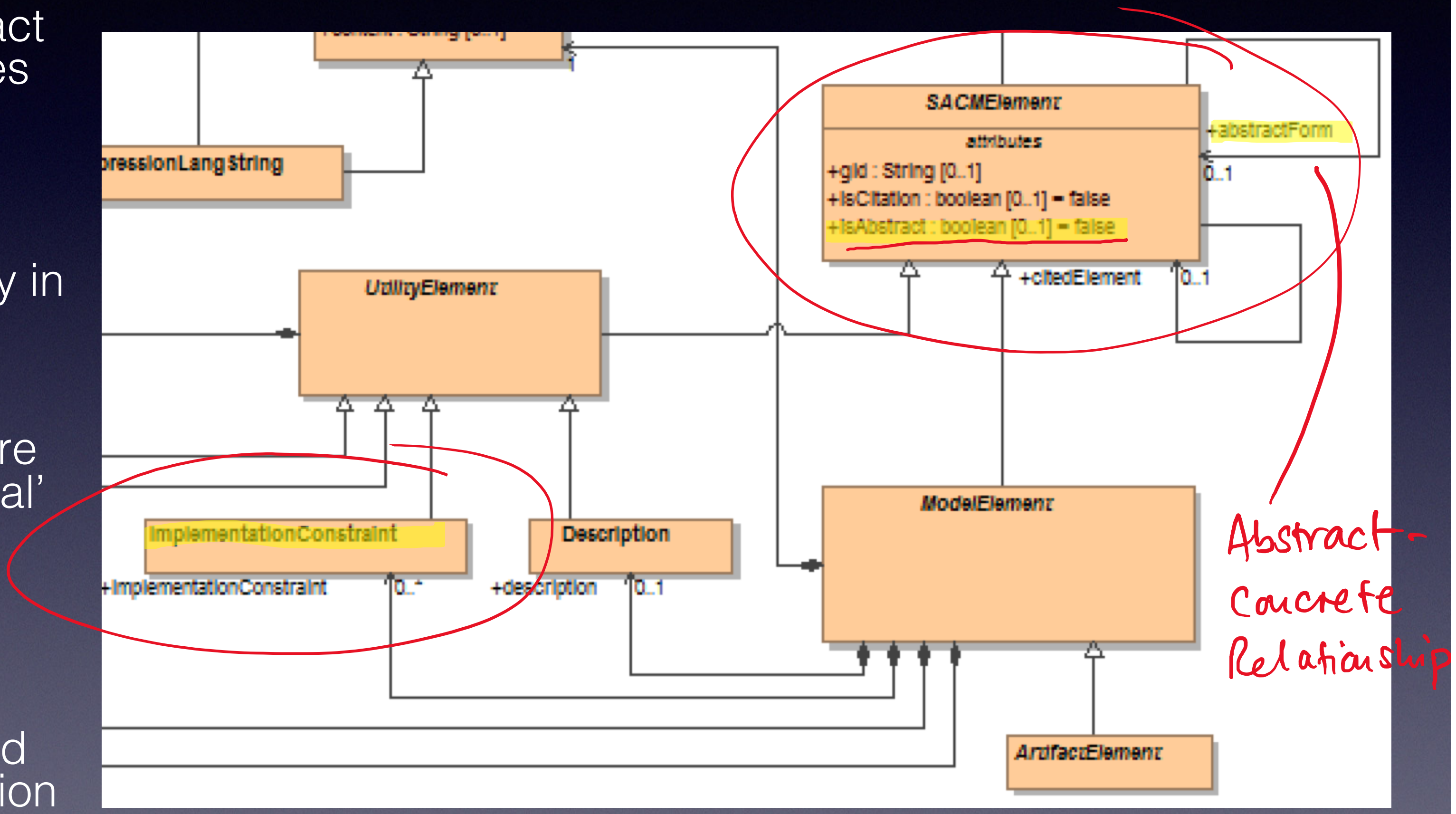
- Modular assurance case management: Managing the division of assurance case arguments and evidence into modules / packages
  - E.g. aligned with architecture, or with supply chain



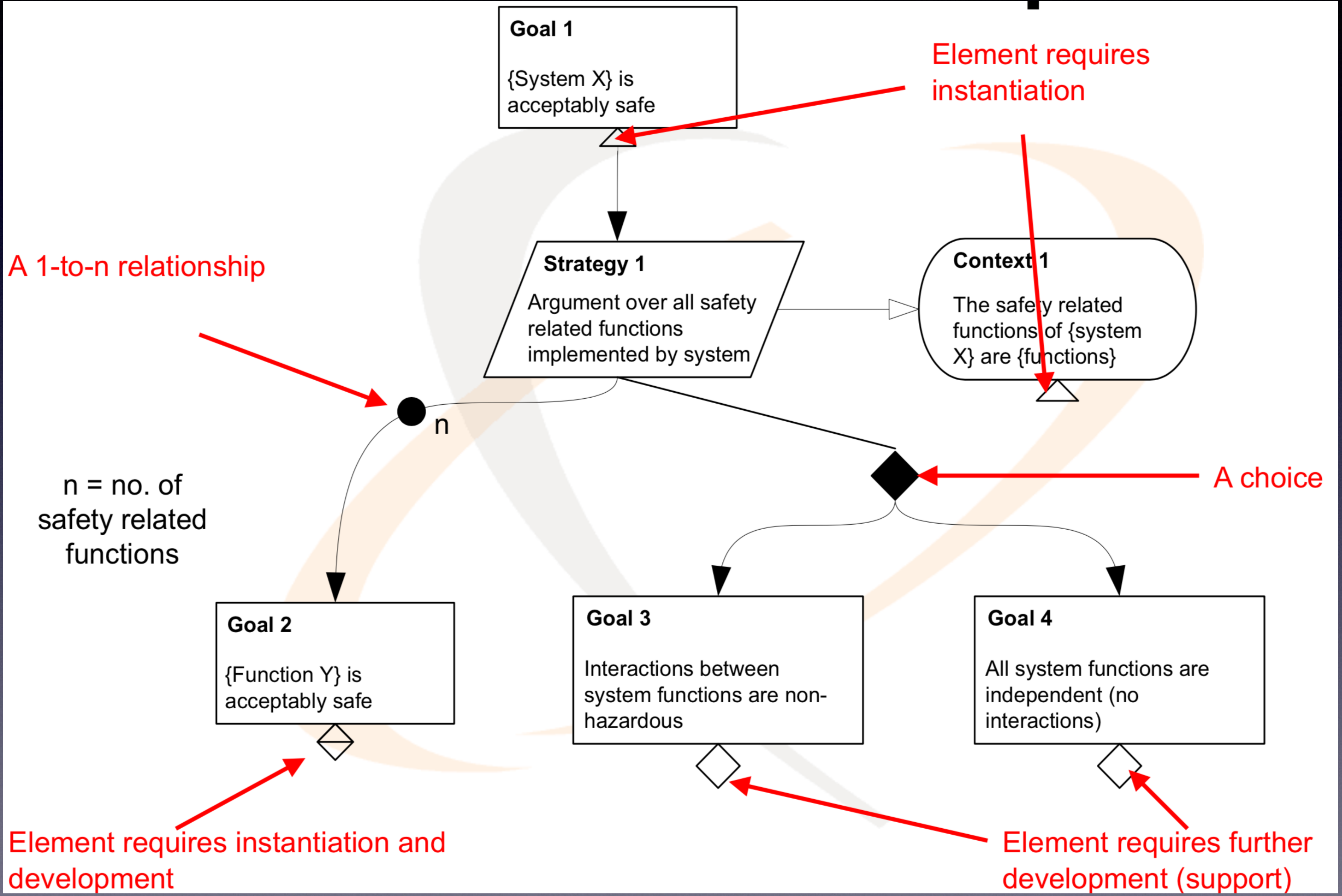


Supporting Patterns

- Patterns are abstract argument structures with appropriate constraints
  - E.g. long history in GSN (1997)
  - Useful to capture reusable, ‘typical’ argument structures
- Patterns in SACM generalised beyond simply argumentation (also Artefact and Terminology)



Example: GSN Patterns


Goal 1
{System X} is acceptably safe
Strategy 1
Argument over all safety related functions implemented by system
Context 1
The safety related functions of {system X} are {functions}
n
Goal 2
{Function Y} is acceptably safe
Goal 3
Interactions between system functions are non-hazardous
Goal 4
All system functions are independent (no interactions)

Element requires instantiation

A 1-to-n relationship

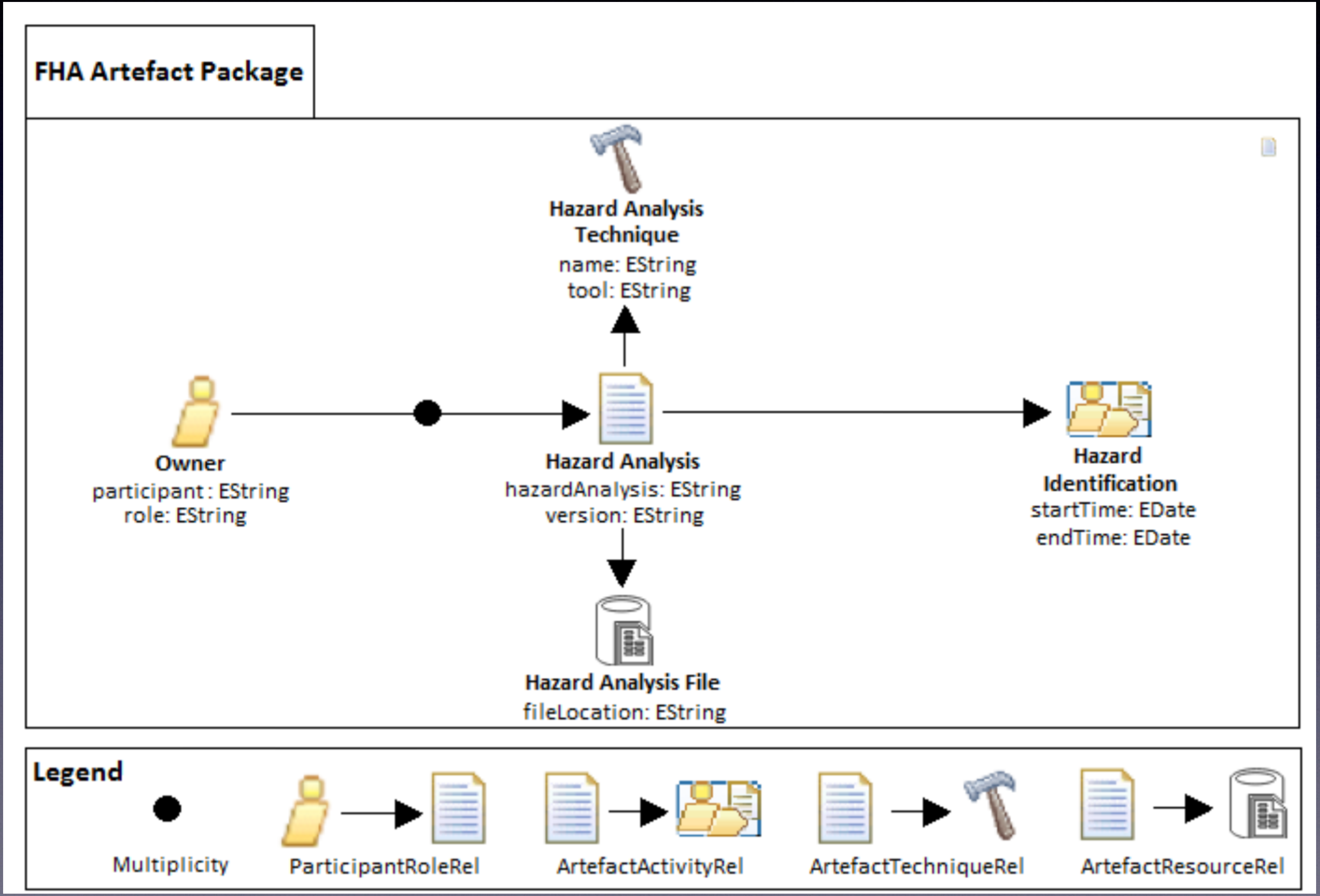
n = no. of safety related functions

A choice

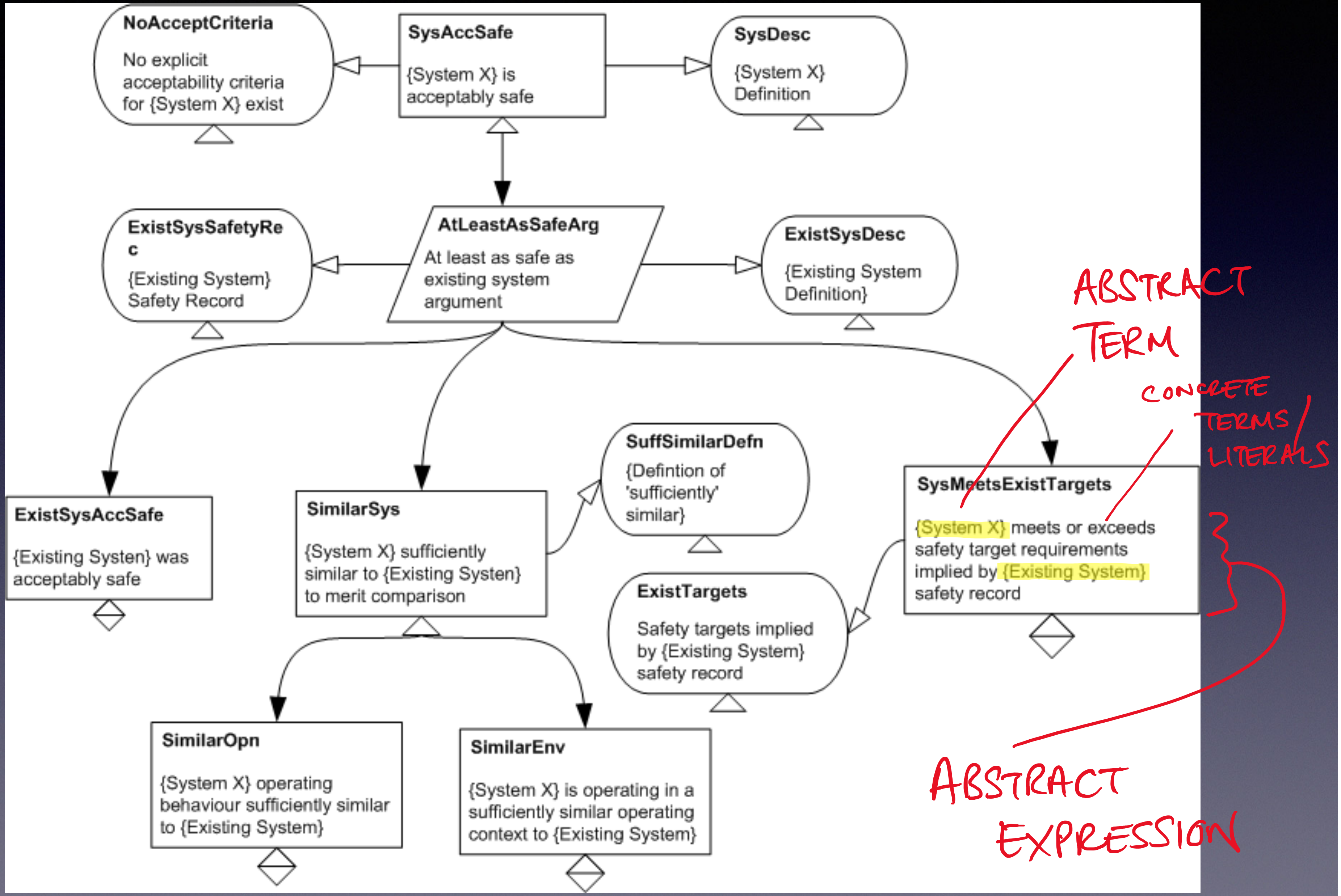
Element requires instantiation and development

Element requires further development (support)

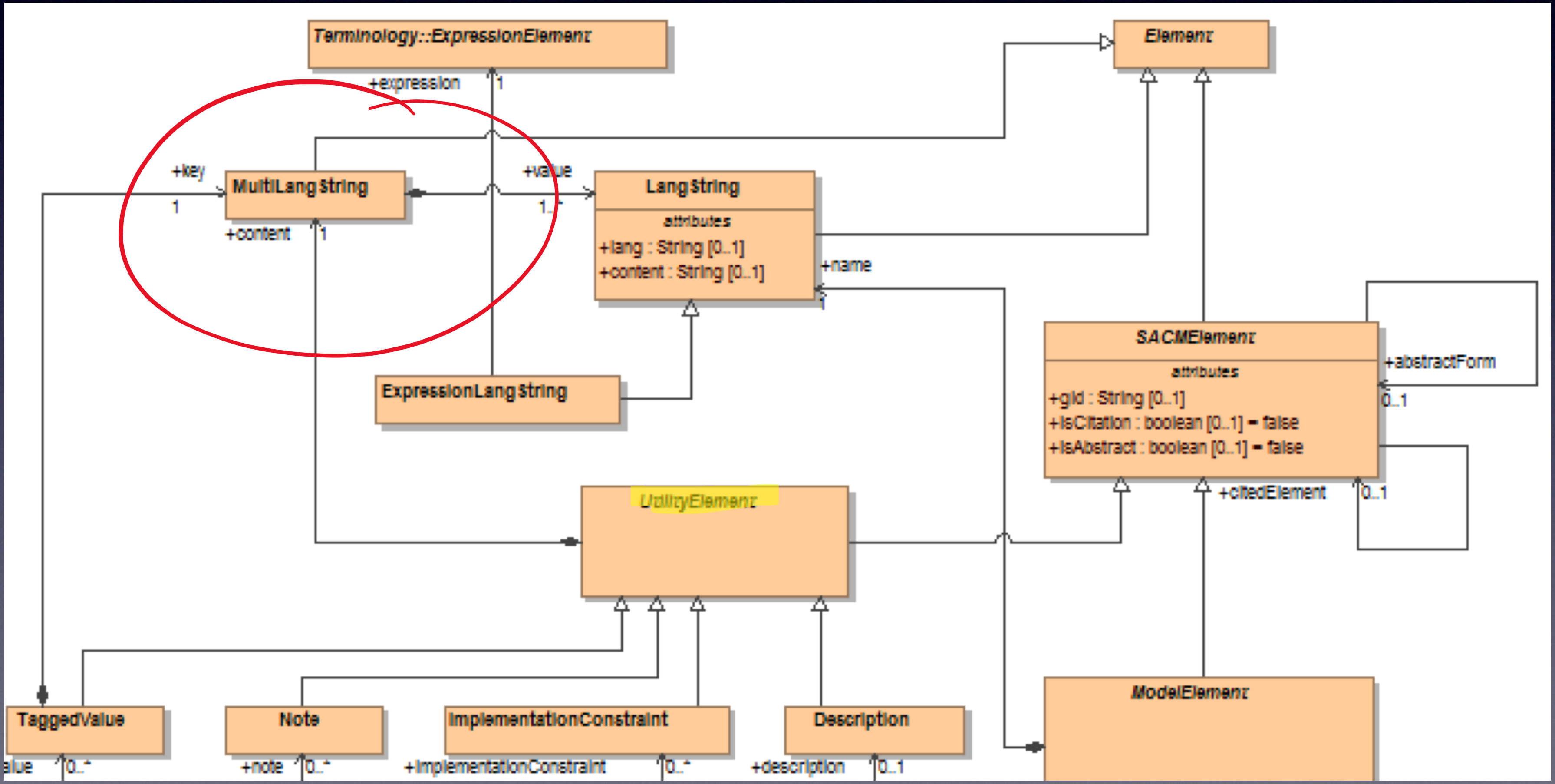
Example: Artefact Patterns



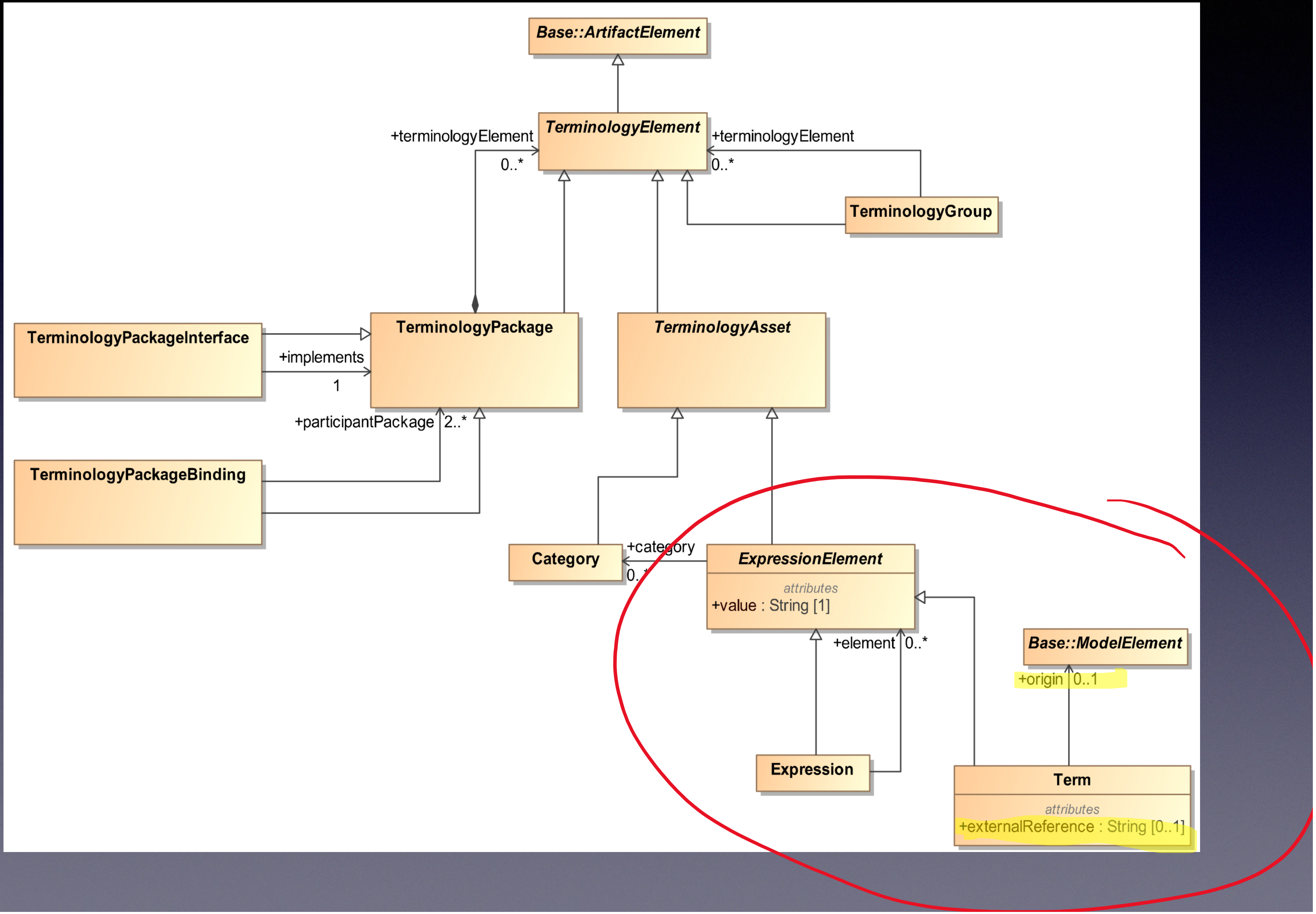
Example: Expression Patterns


NoAcceptCriteria
No explicit acceptability criteria for {System X} exist
SysAccSafe
{System X} is acceptably safe
SysDesc
{System X} Definition
ExistSysSafetyRec
{Existing System} Safety Record
AtLeastAsSafeArg
At least as safe as existing system argument
ExistSysDesc
{Existing System Definition}
ExistSysAccSafe
{Existing Systen} was acceptably safe
SimilarSys
{System X} sufficiently similar to {Existing Systen} to merit comparison
SuffSimilarDefn
{Defintion of 'sufficiently' similar}
ExistTargets
Safety targets implied by {Existing System} safety record
SysMeetsExistTargets
{System X} meets or exceeds safety target requirements implied by {Existing System} safety record
SimilarOpn
{System X} operating behaviour sufficiently similar to {Existing System}
SimilarEnv
{System X} is operating in a sufficiently similar operating context to {Existing System}
ABSTRACT TERM
CONCRETE TERMS / LITERALS
ABSTRACT EXPRESSION

Supporting Machine Processing



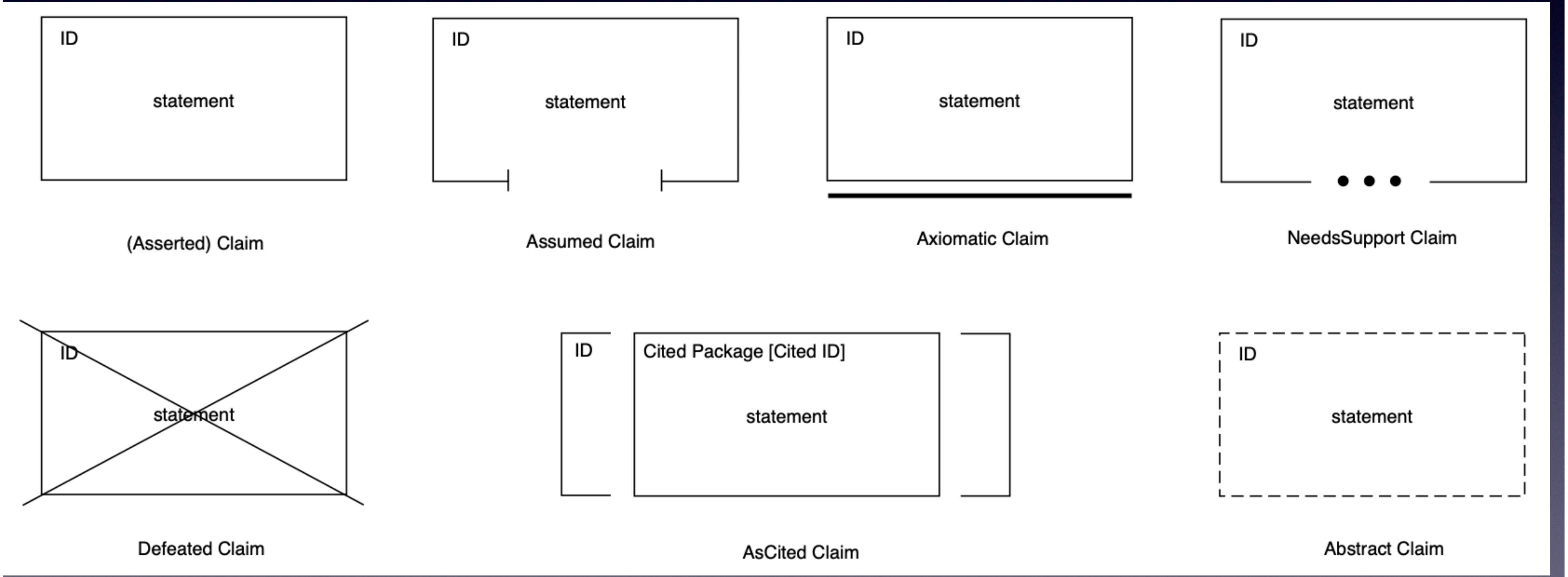
Supporting Structured Natural Language



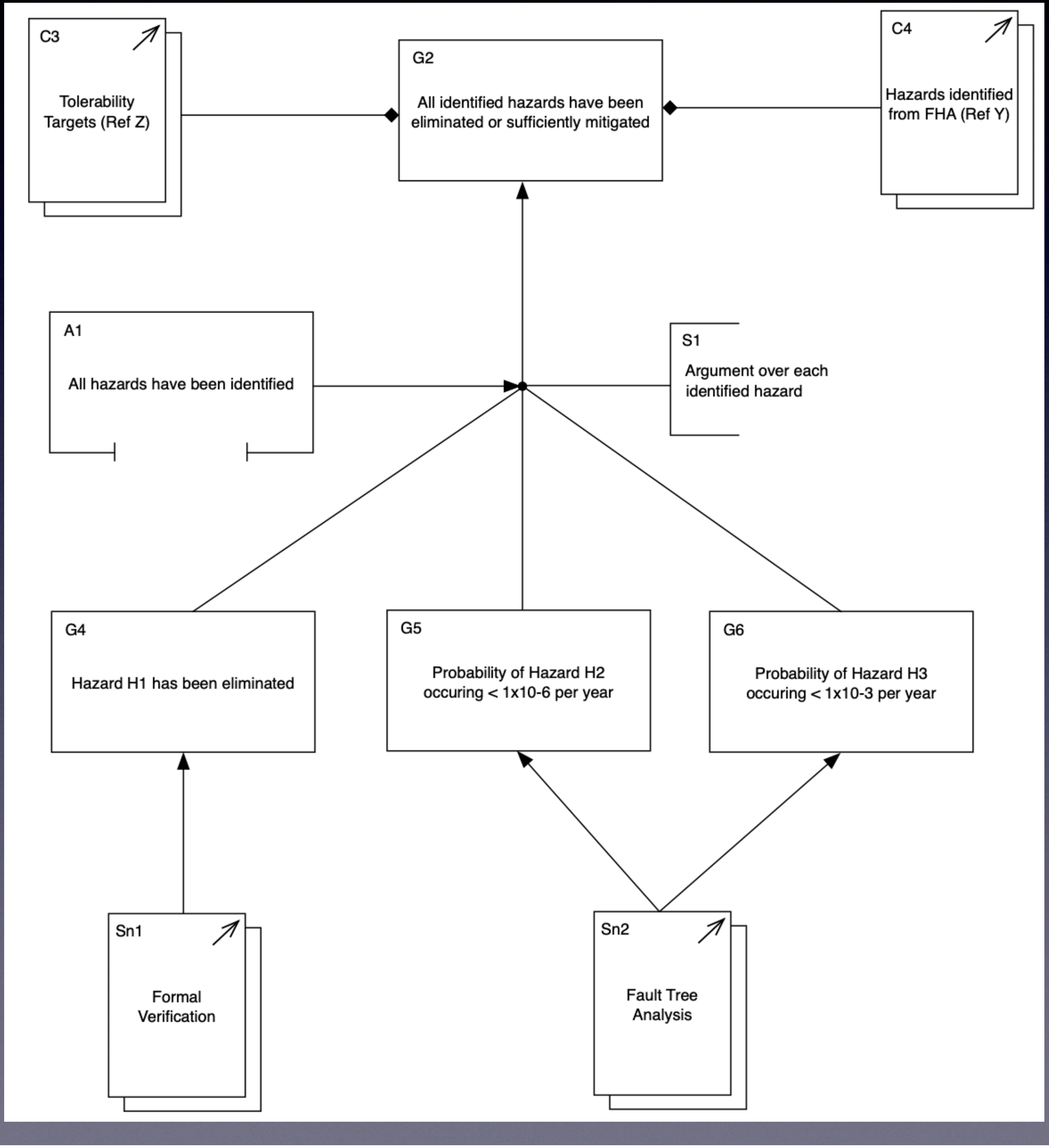
Support beyond Natural Language

- MultiLangString could support several ‘dialects’
  - Formal expressions
  - OCL (e.g. for *ImplementationConstraints)*
- Languages that could support machine evaluation
  - Powerful combination with abstract argumentation, and evidence, structures (and appropriate *ImplementationConstraints)*

SACM Concrete Syntax



SACM Diagrams


C3
Tolerability Targets (Ref Z)
G2
All identified hazards have been eliminated or sufficiently mitigated
C4
Hazards identified from FHA (Ref Y)
A1
All hazards have been identified
S1
Argument over each identified hazard
G4
Hazard H1 has been eliminated
G5
Probability of Hazard H2 occuring < 1x10-6 per year
G6
Probability of Hazard H3 occuring < 1x10-3 per year
Sn1
Formal Verification
Sn2
Fault Tree Analysis

Summary

- Safety case arguments are often informal
- growing interest in formalisation,,
- Some discussion points:
    - value gained over merely ‘structured’ (model-driven) approaches
        - tradeoffs between precision and accessibility
        - whether all forms of argument are equally amenable to formalisation
    - SACM 2 Designed to support all of current (e.g. GSN) practice but not limited to it (e.g. dialectic, better packaging, more support for patterns)
        - Attempting to pave the way towards machine readable and processable arguments