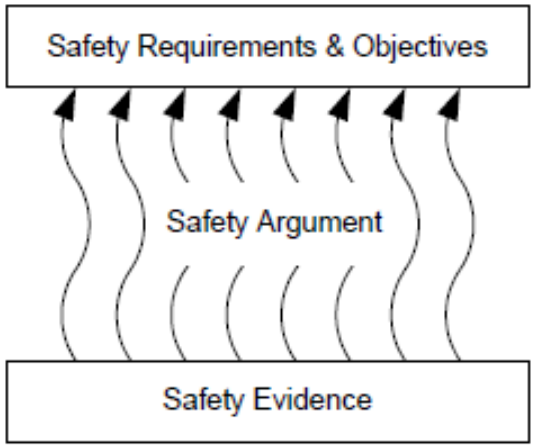
The Safety Case

Structure of Safety Cases
Safety Argument Notation

Budapest University of Technology and Economics
Department of Measurement and Information Systems

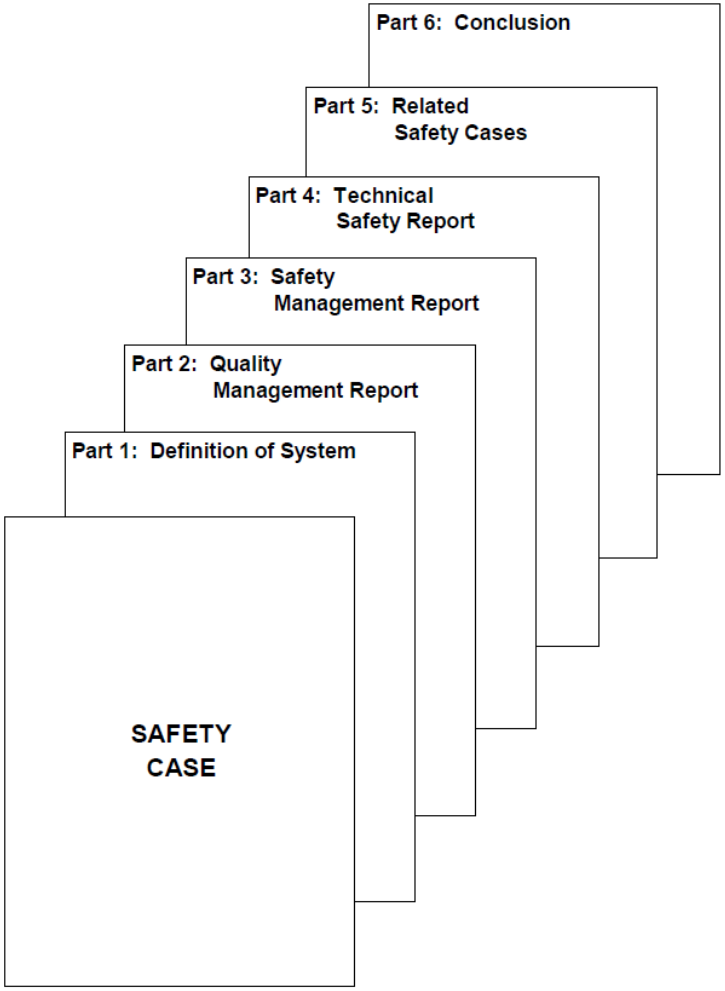
The safety case

- Definition (core): The documented demonstration that the product complies with the safety requirements
- Role:
  - A safety case should communicate a comprehensive and defensible argument that a system is acceptably safe to operate in a particular context
  - Condition for safety acceptance and approval
- To be prepared by: Developers and/or operators
- To be accepted by: Safety authority and/or customer
- Principal elements:
  - Safety requirements (goals, objectives)
  - Arguments (relations)
  - Evidences
    - Analysis results (e.g., FTA, FMEA)
    - Formal verification
    - Test results
    - …



Standard structure of a safety case

- Conditions for safety acceptance
  - Evidence of quality management
  - Evidence of safety management
  - Evidence of technical safety
- Structured presentation of evidence and arguments
- Example: EN50129 (railway)
  - Part 1: Definition of the system
  - Part 2: Quality management report
  - Part 3: Safety management report
  - Part 4: Technical safety report
  - Part 5: Related safety cases
  - Part 6: Conclusion



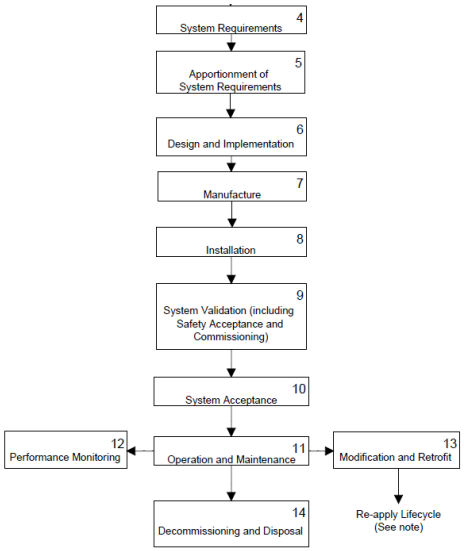
Quality related parts of the safety case

Part 2: Quality management report

- Minimize the incidence of human errors at each stages in the lifecycle: Reduce the risk of systematic faults

Part 3: Safety management report

1. Safety lifecycle: From requirements to validation
2. Safety organization: Roles and competence
3. Safety plan: Activities and approval milestones + review
4. Hazard log: Hazards + risks + risk control
5. Safety requirements
6. System design
7. Safety reviews
8. Safety verification and validation
9. Safety justification
10. System handover (to authority)
11. Operation and maintenance
12. Decommission and disposal



Technical parts of the safety case

Part 4: Technical safety report

1. Introduction:
   - Summary of technical principles and standards
2. Assurance of correct functional operation
   - Architecture, interfaces, fulfillment of requirements, assurance of correct hardware and software behavior
3. Effects of faults
   - Random hardware faults: Quantified safety target
     - Detection, actions after detection, effects, independence, multiple faults
   - Systematic faults: Risk reduction
4. Operation with external influences
   - Demonstration of operability and safety
5. Safety-related application conditions
   - Rules, conditions, constraints
6. Safety qualification tests
   - Evidence to demonstrate completion

Safety argumentation

Communicating safety arguments

- Typical: Free text
  - Structured form (items, enumerations, references)
  - Complex arguments are difficult to describe
    - Review, management, tracking, coordination is difficult

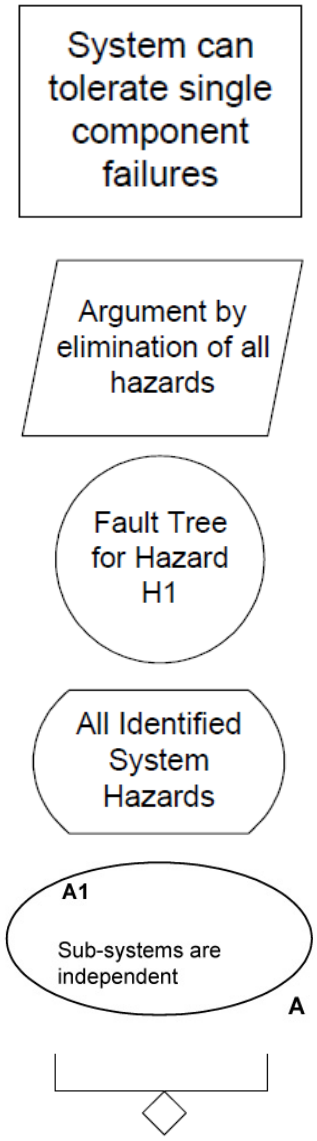
> For hazards associated with warnings, the assumptions of [7] Section 3.4 associated with the requirement to present a warning when no equipment failure has occurred are carried forward. In particular, with respect to hazard 17 in section 5.7 [4] that for test operation, operating limits will need to be introduced to protect against the hazard, whilst further data is gathered to determine the extent of the problem.

?

- Graphical notation: Goal Structuring Notation
  - Elements of safety arguments
  - Relationships between the elements

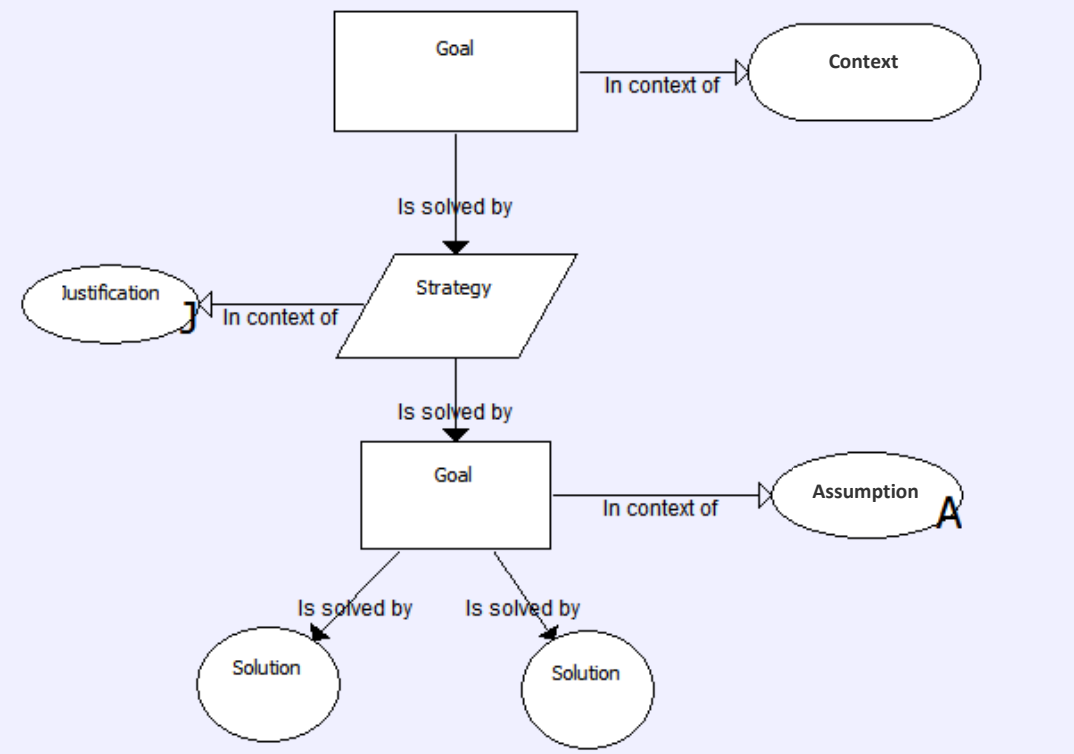
Elements

- Goal: Objective, claim about the system
  - Compliance with requirements
  - Sufficient mitigation / avoidance of hazards
  - Without evidence it is unfounded!
- Strategy: Decomposition method
  - Derivation of sub-goals
- Evidence (solution)
  - Results of observation, analysis, test, simulation, …
  - Fundamental information from which safety can be inferred
- Context
  - Context of demonstrating safety
- Assumption or Justification
  - Limits, conditions etc.
- Undeveloped goal
  - Further development is necessary

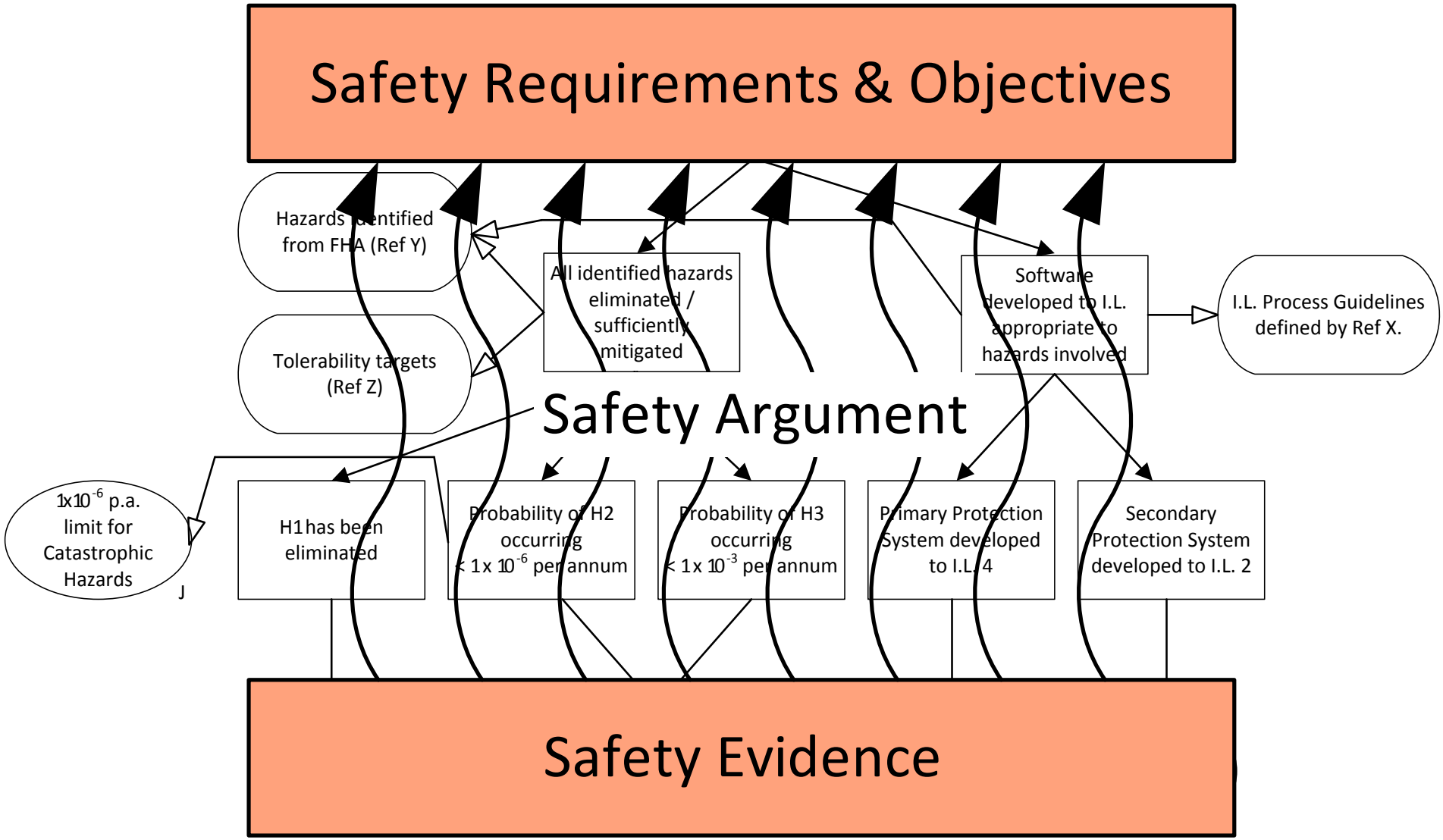


Relations

- "Is solved by"
  - Applied between goals, strategies, evidences
- "In context of"
  - Applied between contexts / assumptions / justifications and other elements

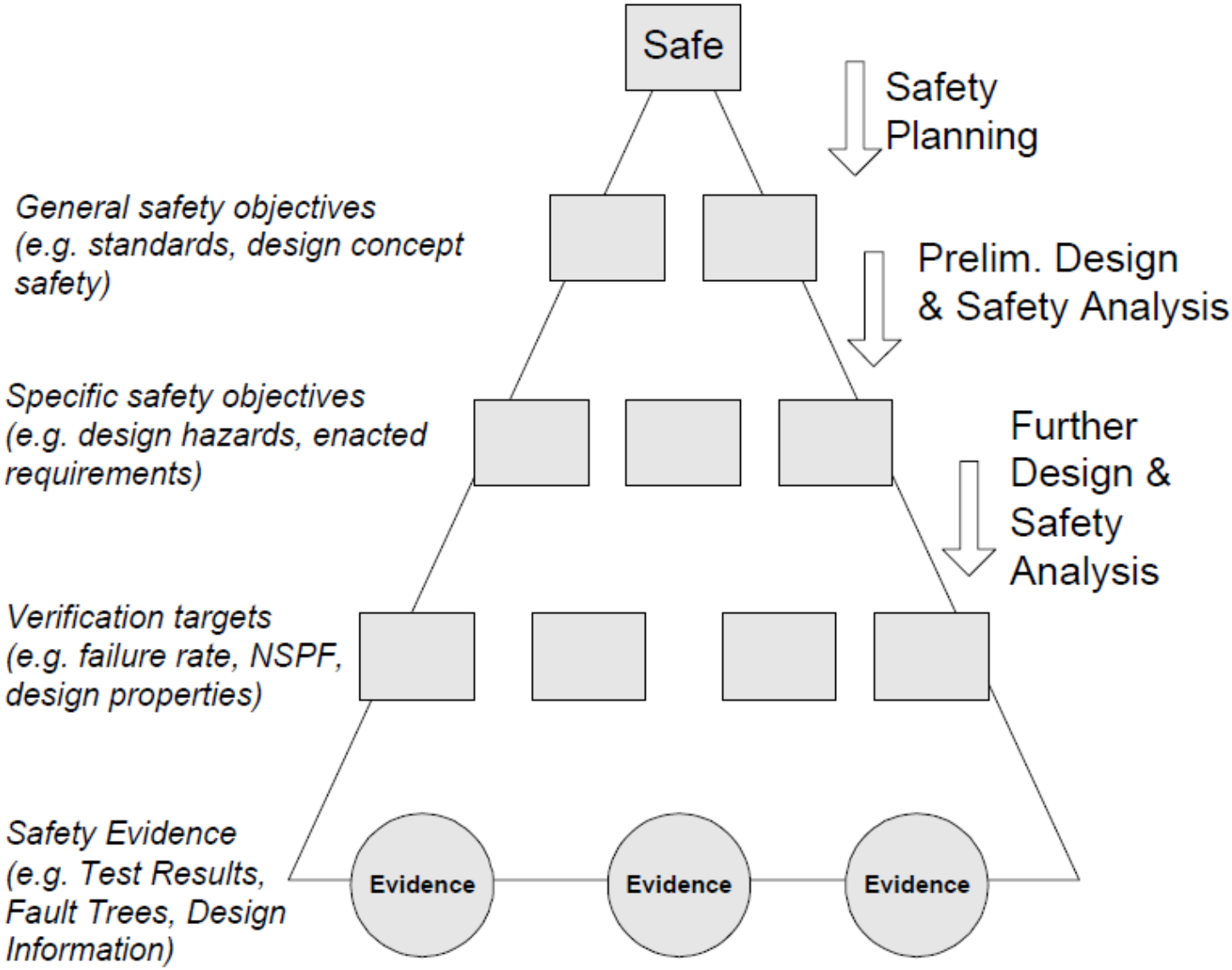


Overview of safety argumentation

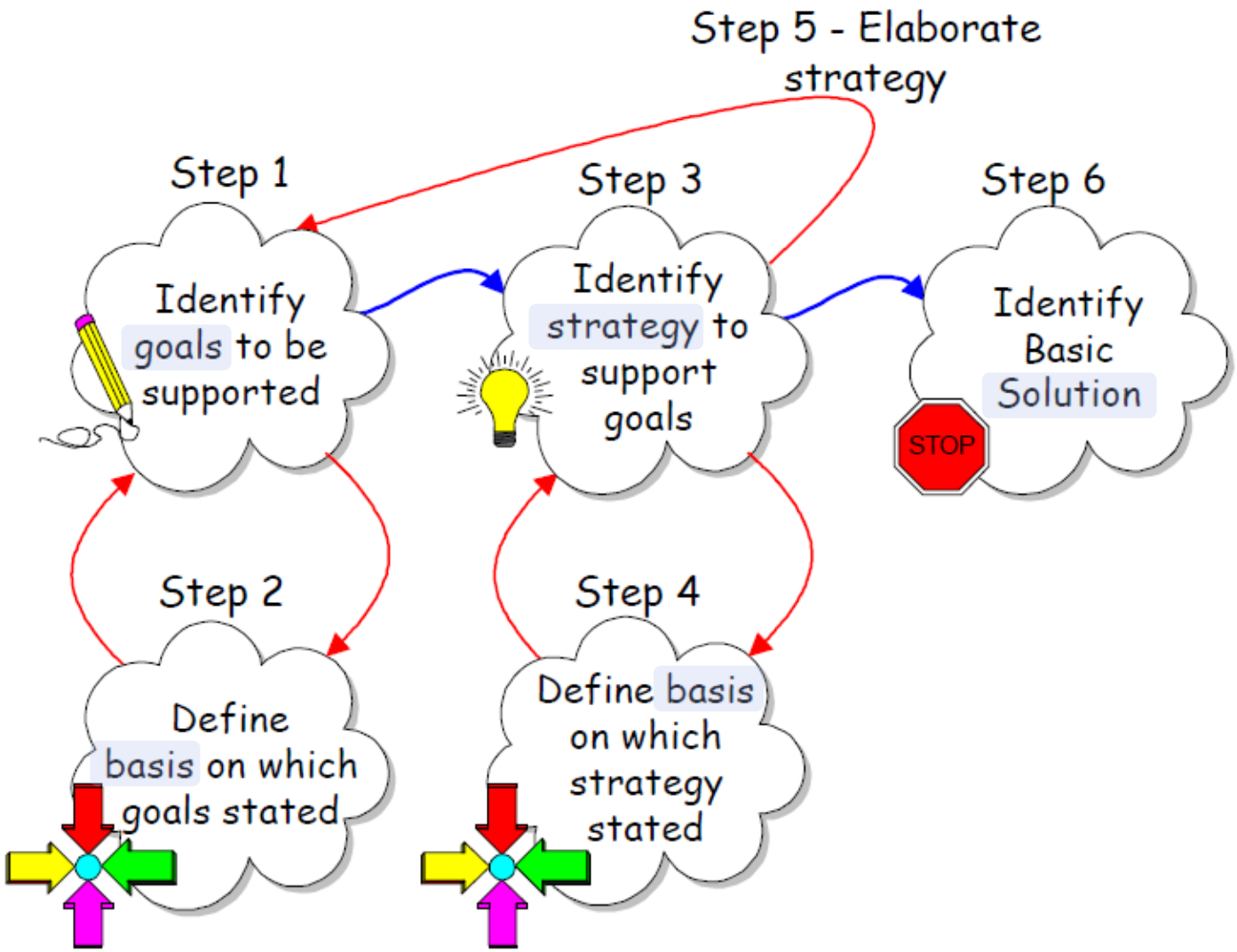


Source: T. Kelly

Evolution of the goal structure

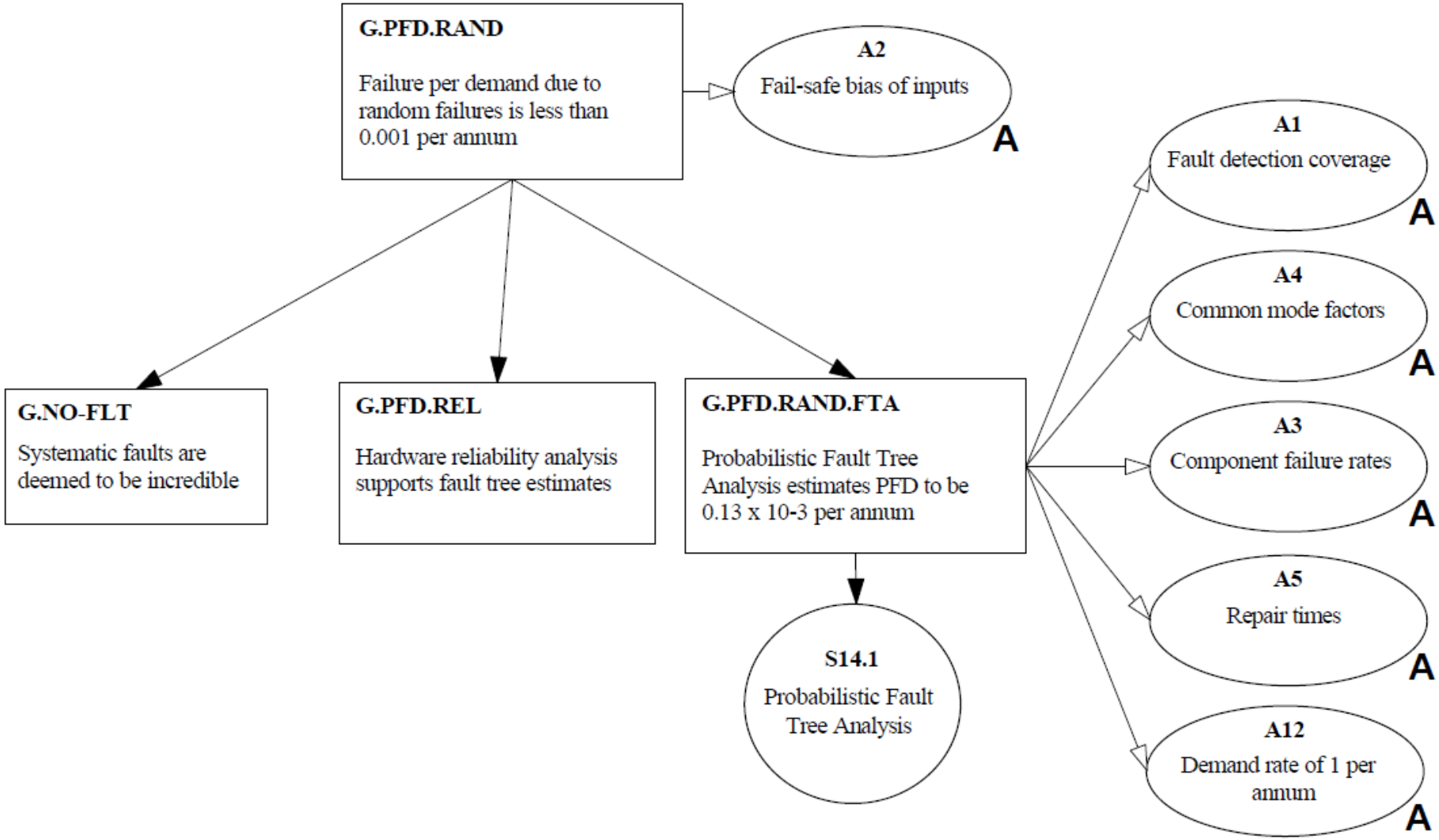


Steps of safety case construction



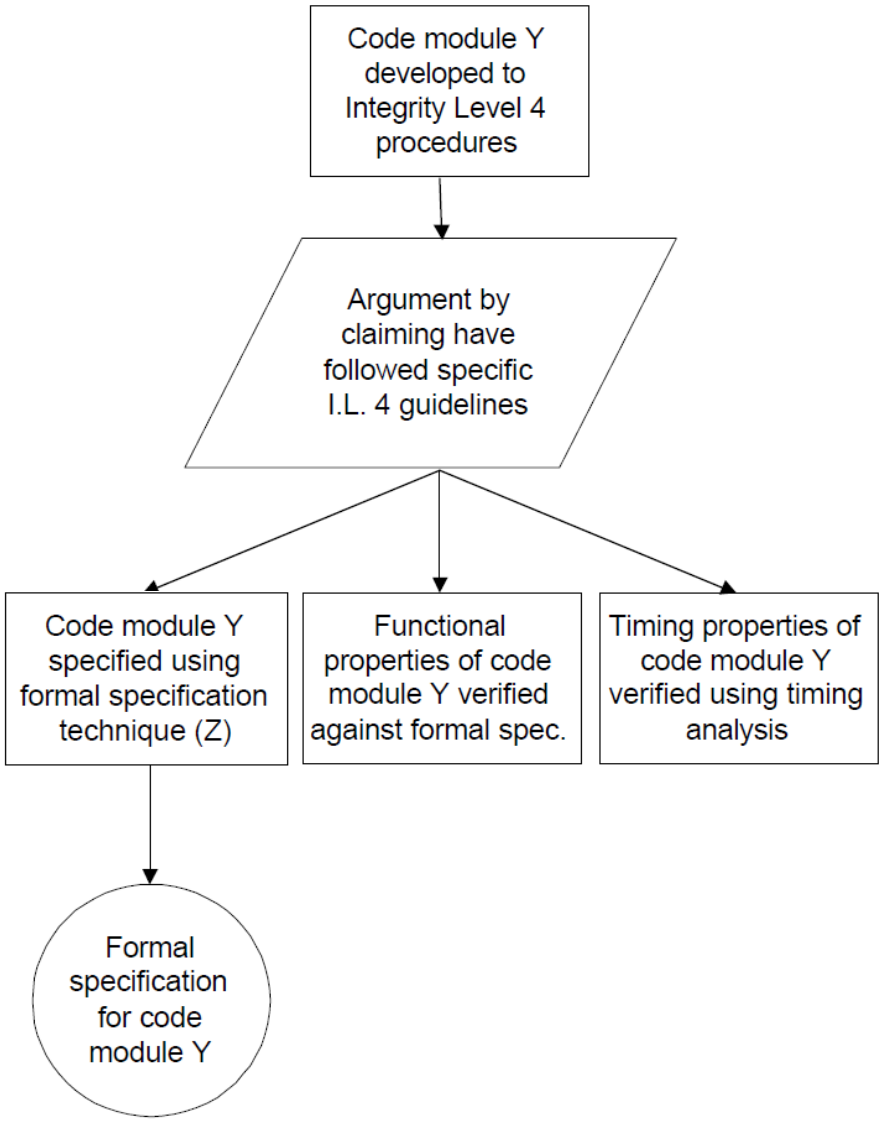
Source: T. Kelly

Safety arguments for hardware

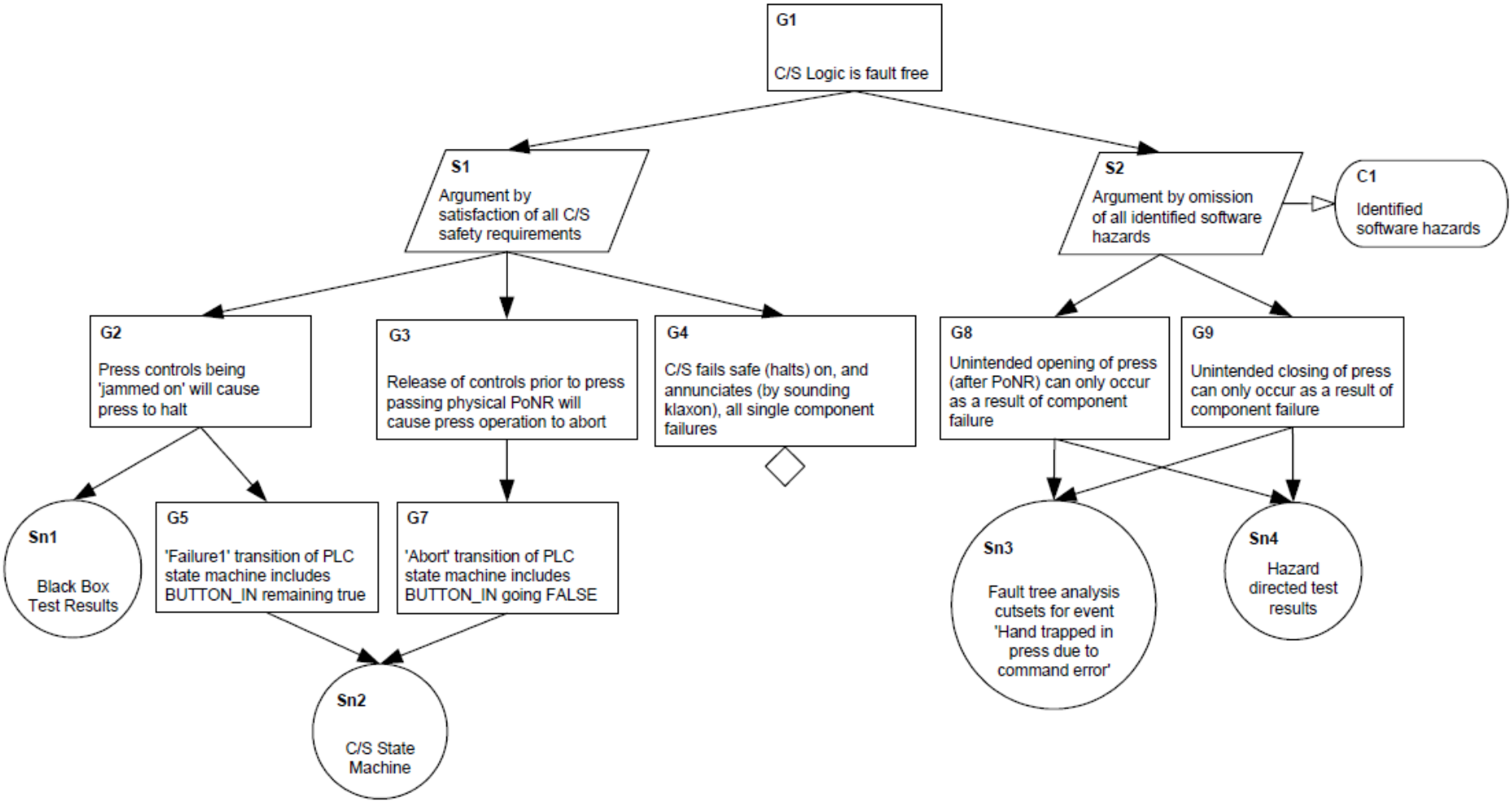


Safety arguments for software

- Software SIL: Required techniques and measures form arguments and evidences
- Example: Guidelines followed for SIL4
  - Formal specification
  - Formal verification of functionality
  - Formal verification of timing

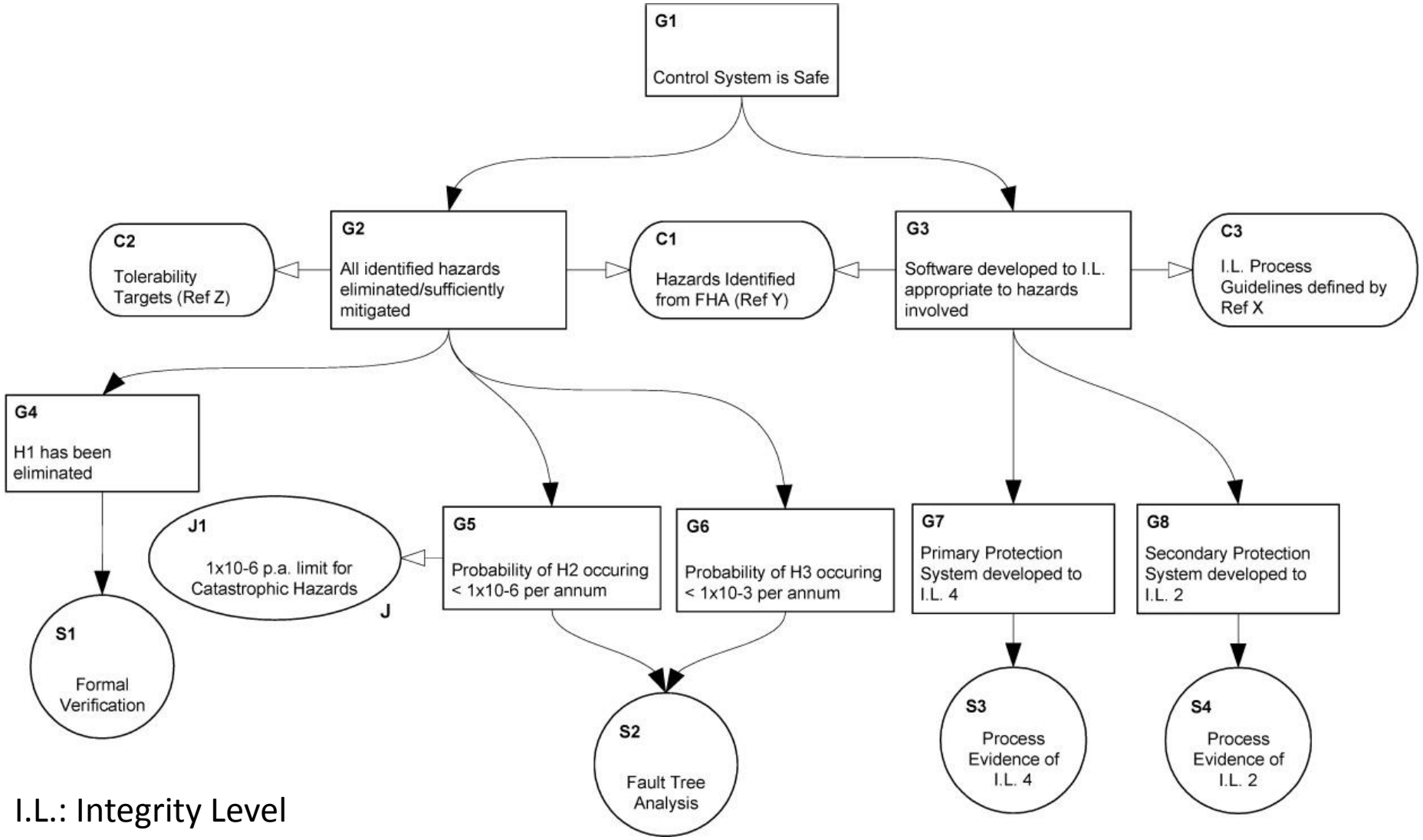


An example goal structure



Evidences: Test results, state machine analysis, fault tree analysis, directed testing

Generic goal structure



I.L.: Integrity Level

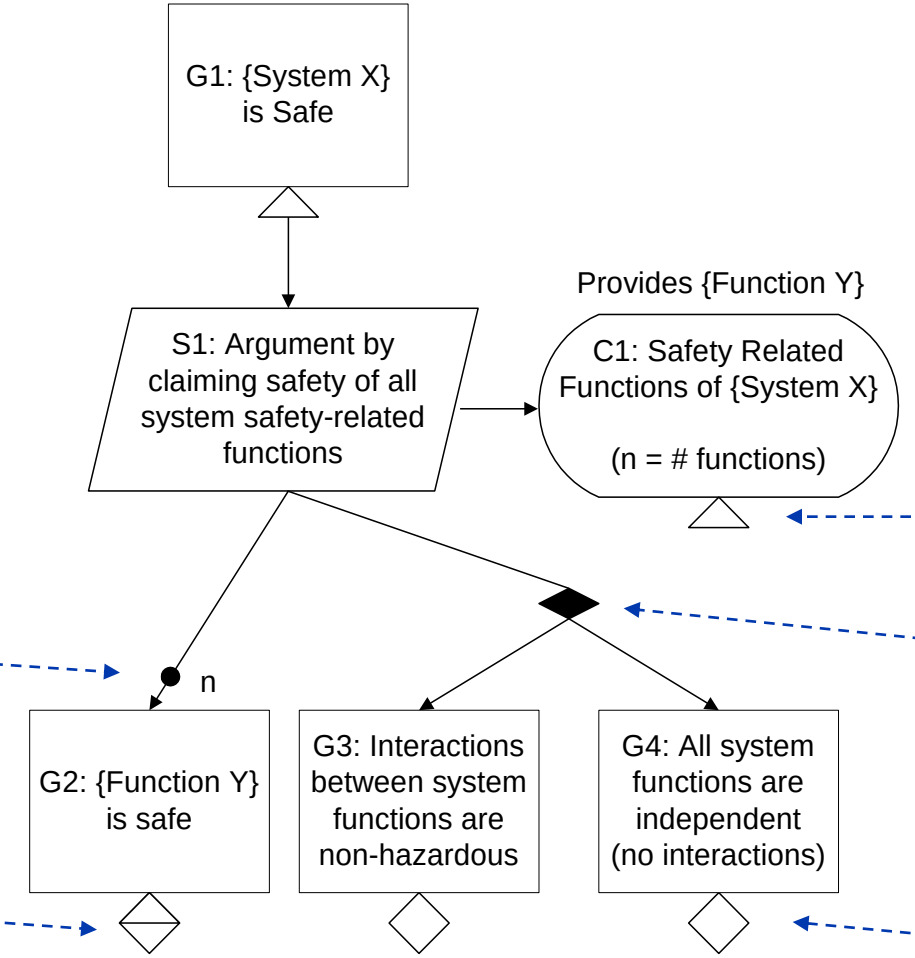
FHA: Functional Hazard Assessment

Safety case patterns

- Combines argumentation and patterning
  - Supports the re-use of successful argument approaches (best practice)
  - Focus on semantics rather than the syntax of the safety case
- GSN extensions to support capturing patterns
  - Multiplicity
  - Instantiation
  - Develop
  - Instantiation and develop
  - Choice

Example of a GSN pattern

Decomposition on the basis of system functions



To be instantiated

Multiplicity

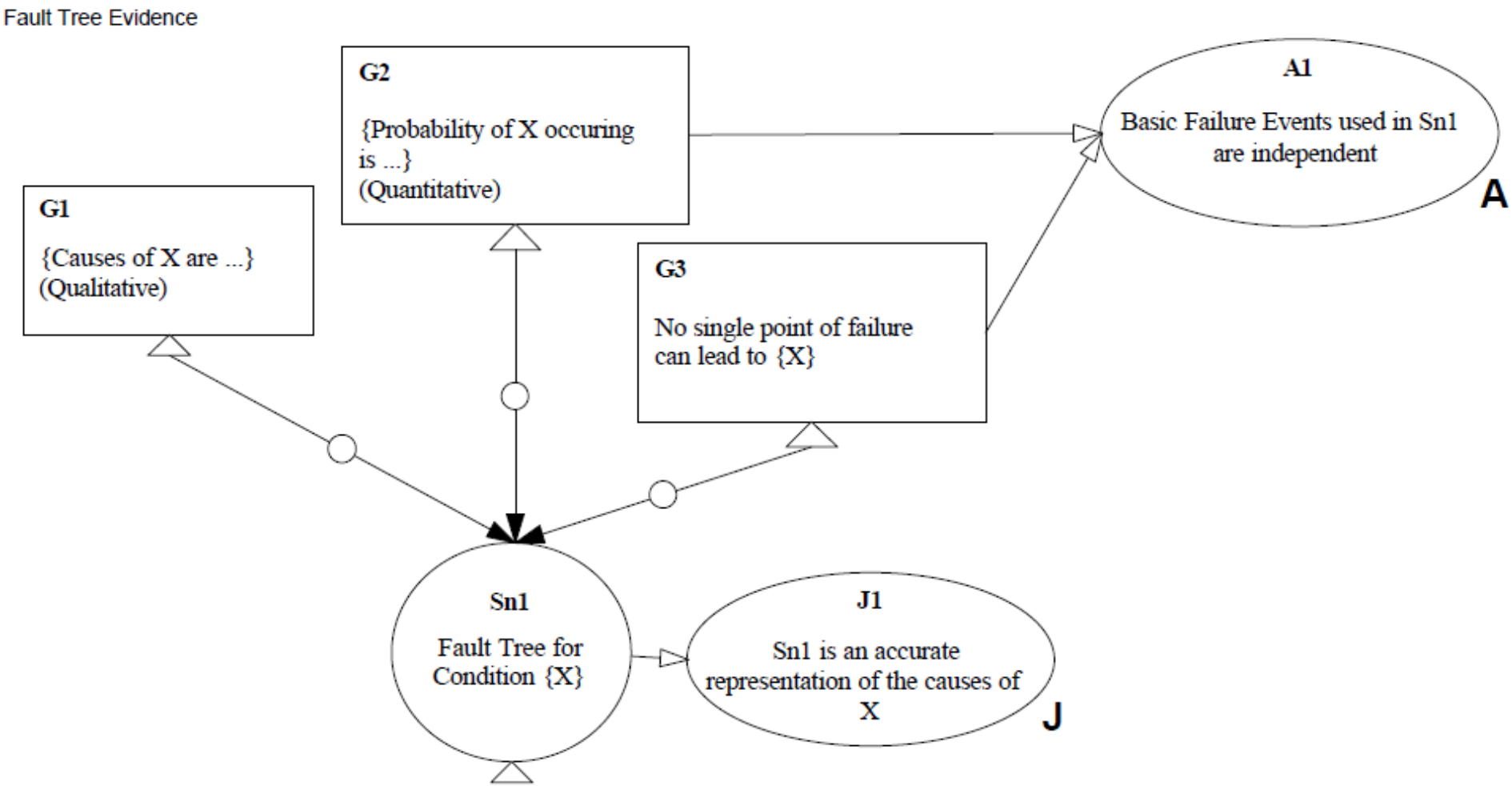
Choose

To be instantiated and developed

To be developed

The Fault Tree pattern

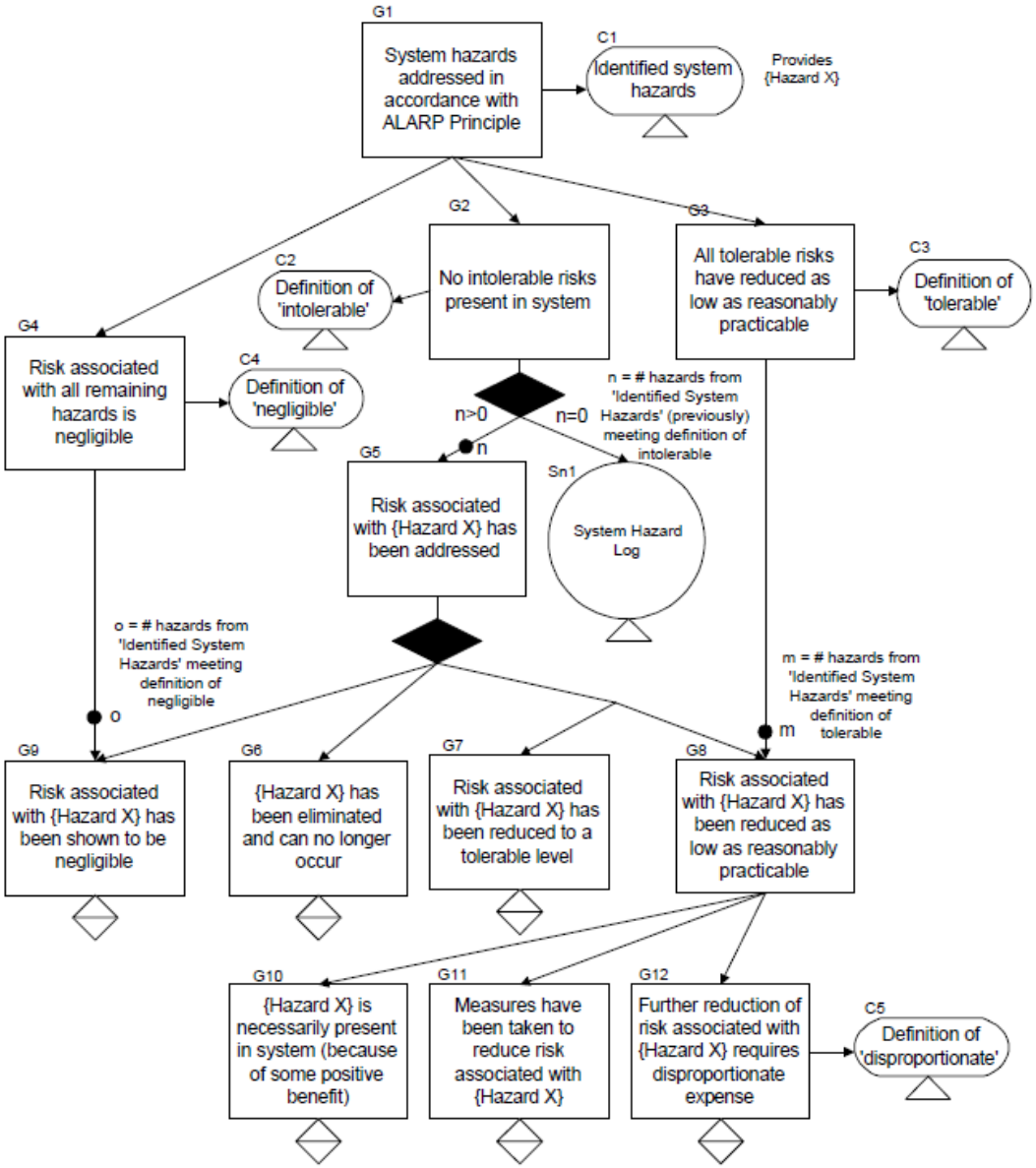
How a fault tree analysis can be used as evidence



The ALARP pattern

ALARP: As Low As Reasonably Practicable

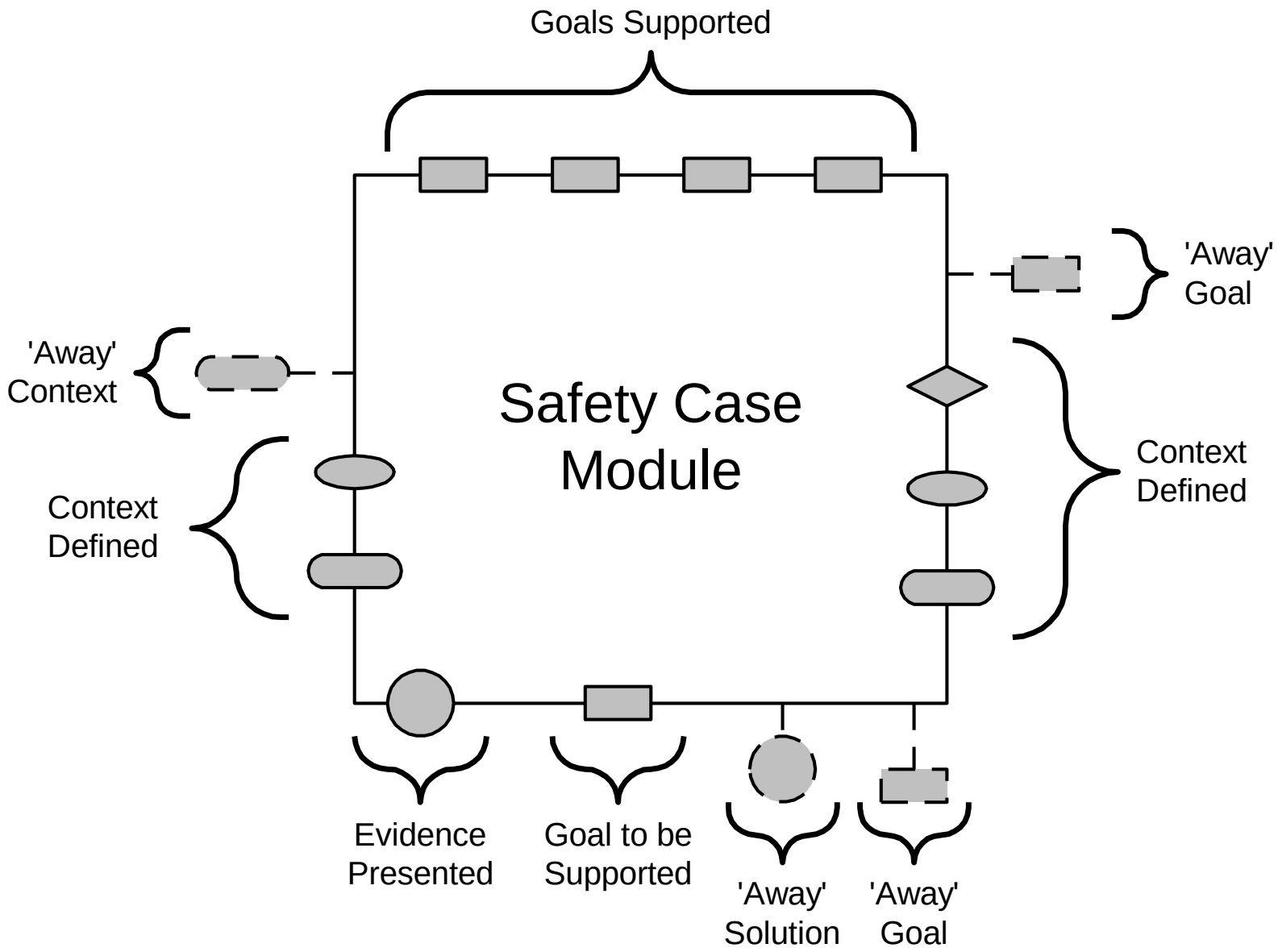
- No intolerable risk
- All tolerable risks have reduced as low as reasonably practicable
- All remaining hazards have negligible risks



Modular safety cases

- Goal: Modular, compositional construction of safety cases (corresponding to system structure)
- Partitioning of modules
  - Vertical (hierarchical) partitioning
    - Claims of one argument are objectives of another
    - E.g., case split of system and software safety case
  - Horizontal partitioning
    - One argument providing the assumed context of another
    - E.g., "All system hazards have been identified"
      provides assumed context of an argument that
      "All identified system hazards have been sufficiently mitigated"
- Module interfaces
  - Dependency of objectives, evidence, context of other modules

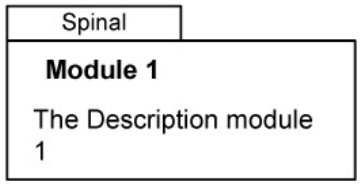
Principle of safety case interface



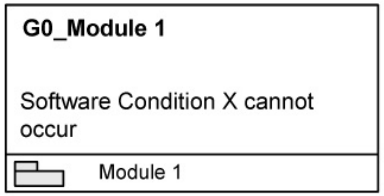
Example of a modular safety case

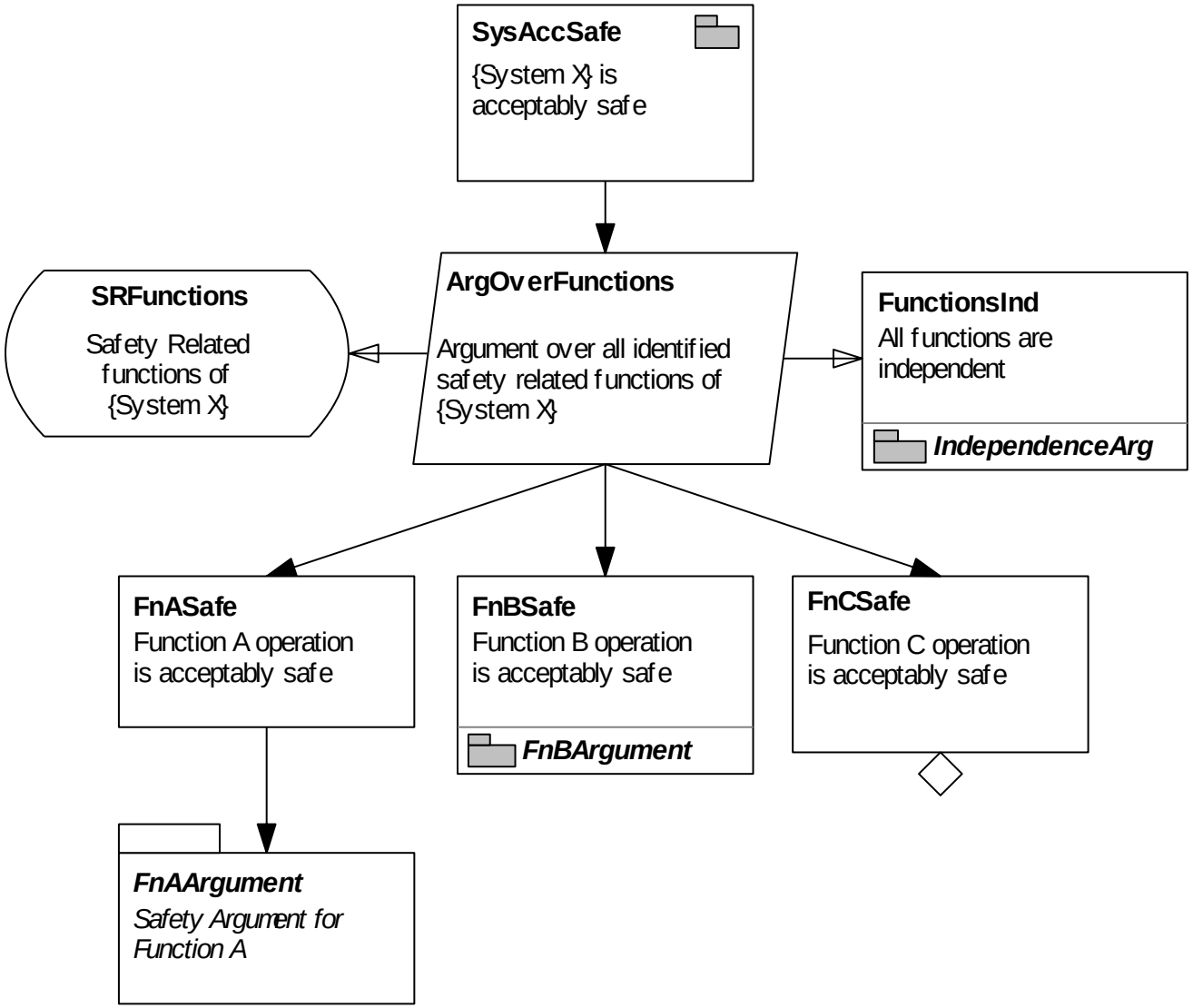
Elements:

- Safety case modules



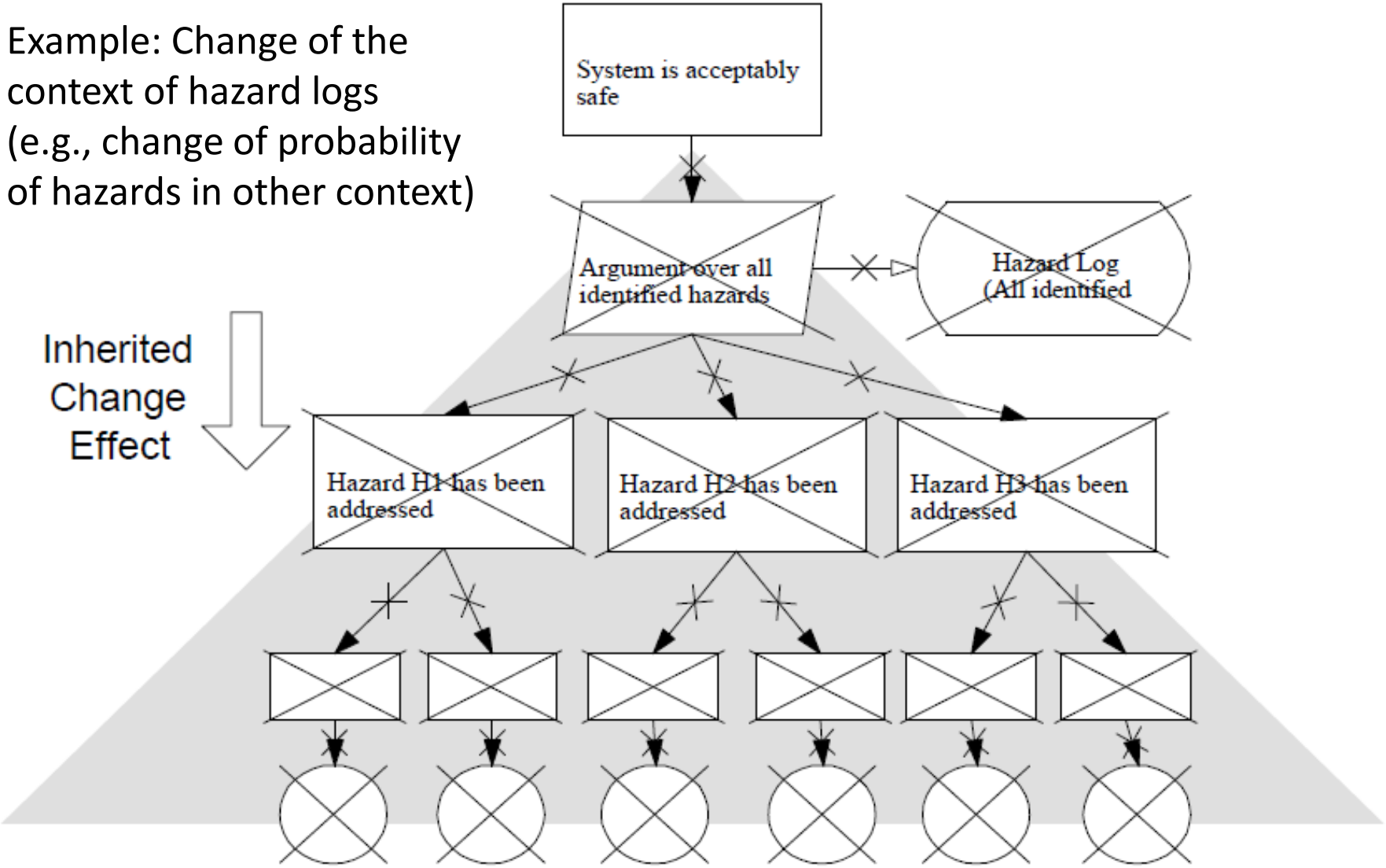
- "Away" goals





Management of safety cases

Example: Change of the context of hazard logs (e.g., change of probability of hazards in other context)

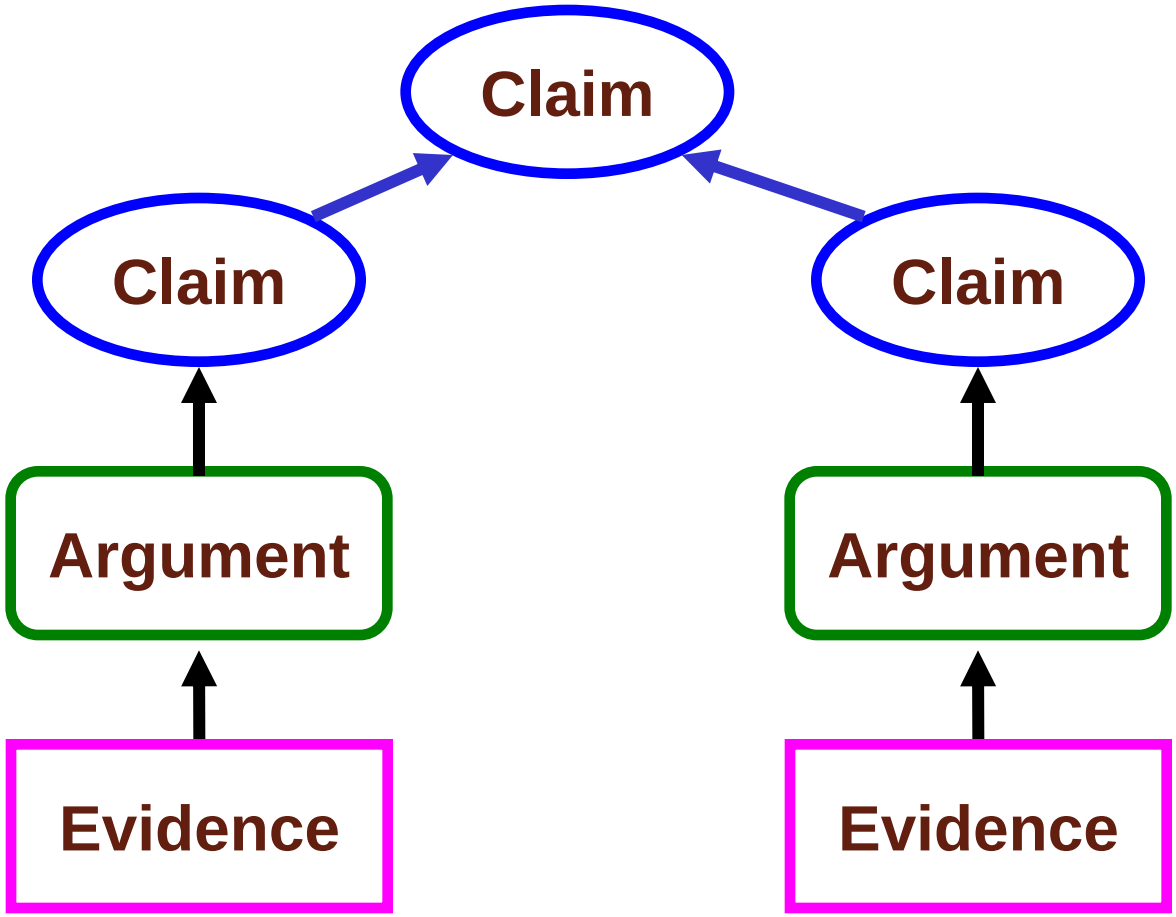


Advantages and disadvantages of GSN

- Advantages:
  - Simple elements
    - Captures the elements most important to safety arguments
  - Structured hierarchical breakdown
    - Method guidance exists
  - Semantics well defined and understood (first order logic)
  - Can be used at various stages of argument development
  - Increasingly being adopted by companies
- Disadvantages:
  - Easy to read, harder to write ☺
  - Doesn't stop you writing bad arguments ☹

Other approaches

- ASCAD: Adelard Safety Claims Arguments Data
  - Claim: Assertion to be proven
  - Argument: How evidence supports claim
  - Evidence: Required observation, analysis, test, …

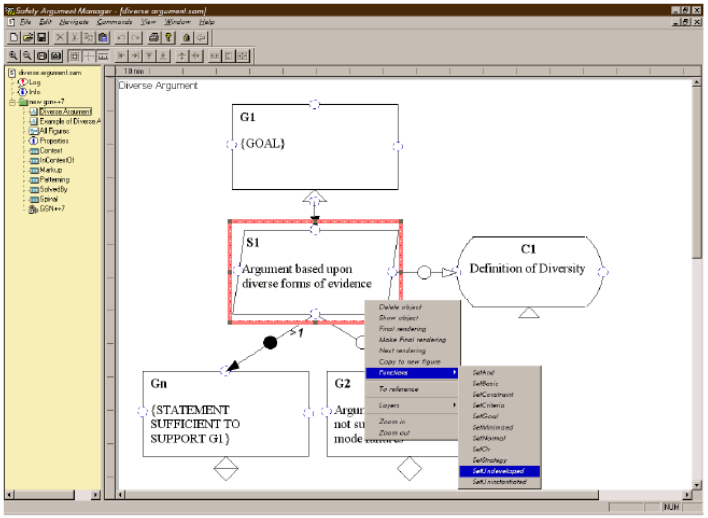


Generalization

- Assurance cases
  - Safety cases
  - Security cases
  - Dependability cases
- Definition
  - A documented body of evidence that provides a convincing and valid argument that a specified set of critical claims regarding a system's properties are adequately justified for a given application in a given environment
- Examples of using assurance cases
  - Security-critical applications: Based on Common Criteria
  - Medical devices: Based on ISO 14971

Supporting tools

- Adelard Safety Case Editor (ASCE)
  - Adelard, www.adelard.co.uk
  - Supports both GSN and ASCAD
- E-Safety Case
  - Praxis HIS, www.esafetycase.com
- GSN CaseMaker
  - ERA Technology, www.era.co.uk
- ISCADE (Integrated Safety Case Development Environment)
  - RCM2, www.iscade.co.uk
- ISIS
  - High Integrity Solutions, www.highintegritysolutions.com
- Freeware Visio Add-on
  - University of York, http://www.cs.york.ac.uk/~tpk/gsn/gsnaddoninstaller.zip



Summary

- Structure of safety cases
  - Evidence of quality management
  - Evidence of safety management
  - Evidence of technical safety
- Safety argumentation – presented using the Goal Structuring Notation
  - Elements: Evidence, Strategy, Goal, Context
  - Patterns
  - Modular safety arguments
  - Maintenance of safety arguments
- Generalization: Assurance cases