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Safety Assurance of Software and ML Development for Nuclear Instrumentation and Controls

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Abstract

Digital instrumentation and control (DI&C) systems monitor and control parameters in nuclear power plants. Ensuring their safety is a critical part of ensuring overall plant safety. Nuclear power plant licensing generates thousands of safety documents that could be organized more effectively using a safety assurance case (SAC). We conducted a literature survey of SACs and created a SAC framework for DI&C software using Goal Structuring Notation (GSN). This framework focuses on four software development processes: management & assurance, pre-developed software (PDS) qualification, the Software Development Life Cycle (SDLC), and the Machine Learning Development Life Cycle (MLDLC). We organized our framework using a novel level structure that can be applied to other SACs to improve their clarity. Finally, we demonstrate how our framework can be incorporated as part of a SAC for a larger reactor system.

Objectives

- To organize safety arguments from the literature, U.S. Nuclear Regulatory Commission documents, and international standards
- To develop a SAC framework for DI&C software that is adaptable to any SDLC or MLDLC model

Safety Assurance Cases

- A SAC is a structured argument to demonstrate a product's safety to stakeholders [1, 2]
- **Functional** requirements: the system **performs required functions** [3]
- **Process** requirements: **quality of the system development** process [3]
- Software is complex – cannot ensure safety through test cases alone [3]
- Machine learning (ML) techniques can introduce even more uncertainty and complexity [4]
- Hence, process requirements are the focus of this framework (Goal G5)

Development Life Cycles

- The SDLC (G9) and MLDLC (G10) are a list of phases with defined activities.

Example SDLC model [5]

1	Conceptual design
2	System requirements
3	Detailed system design
4	Implementation
5	Testing
6	Installation & site acceptance testing
7	Operations & maintenance
8	Retirement

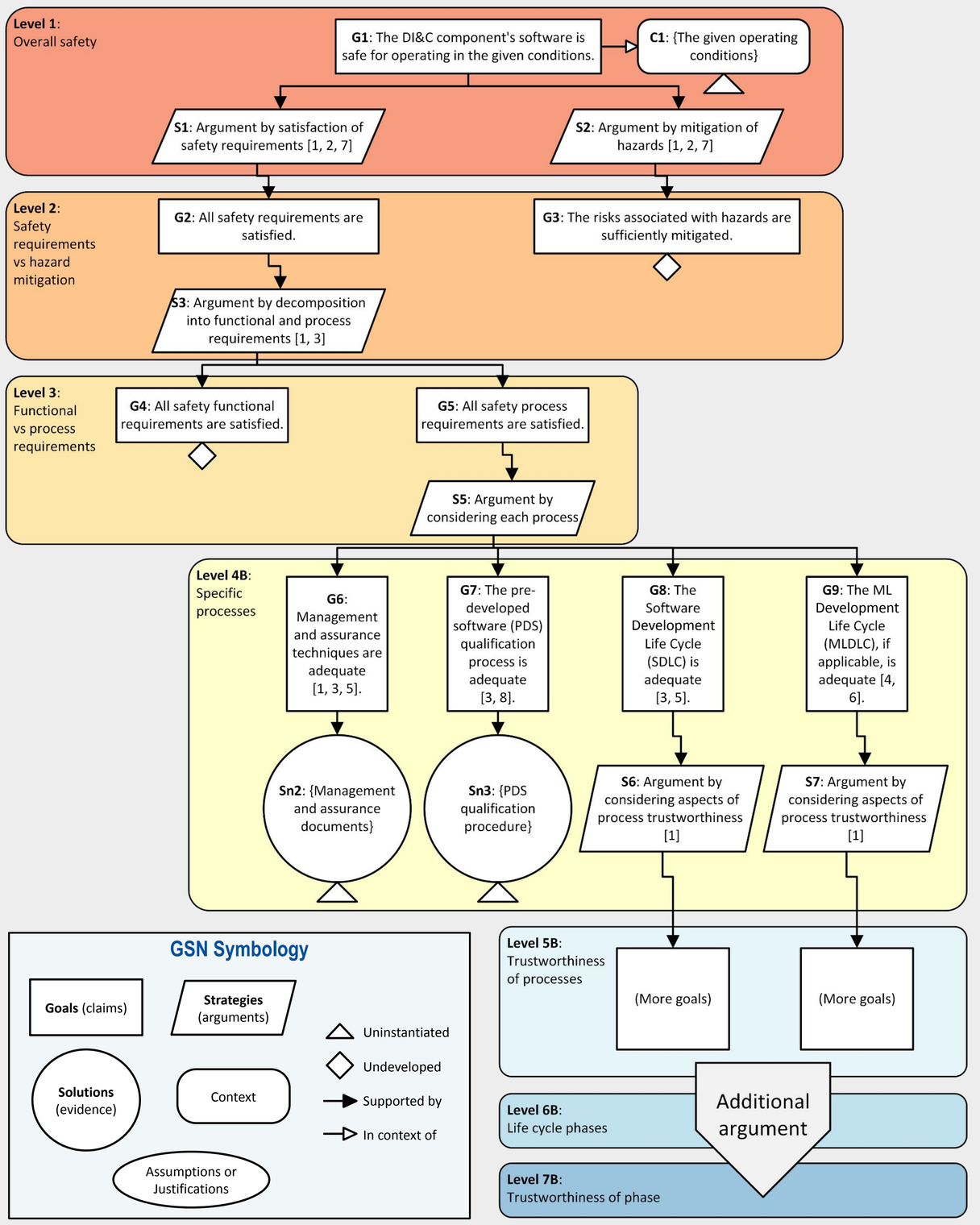
Example MLDLC model [6]

1	ML safety assurance scoping
2	ML requirements
3	Data management
4	Model learning
5	Model verification
6	Model deployment

Conclusion & Future Work

- **Conclusion**: We have developed a SAC framework for DI&C software and introduced a classification of levels to increase clarity and organization for safety management.
- **Future work**: Develop additional branches of the framework and demonstrate its usage via a case study on the Core Protection Calculator System of the APR1400's reactor trip system.

Proposed SAC Framework Overview



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