

Hazard Analysis and Validation Metrics Framework for System of Systems Software Safety

James Bret Michael, *Senior Member, IEEE*, Man-Tak Shing, *Senior Member, IEEE*, Kristian John Cruickshank, and Patrick James Redmond

Abstract—Safety-critical software-intensive systems of systems require rigorous verification and validation to ensure that they function as per requirements. Unlike verification, validation is typically an ill-defined activity for software development. This paper presents a well-defined validation metrics framework which uses hazard analysis, and the derived software requirements for mitigating the identified hazards, as proxies in gauging the sufficiency of the software safety requirements early in the software development process. Moreover, traditional hazard analysis techniques are insufficient to deal with the complexity and size of systems of systems. This paper examines the nature and types of hazards associated with systems of systems and presents a new technique for analyzing one type of emergent hazard known as an interface hazard.

Index Terms—Goal question metric, goal structuring notation, hazard analysis, interface hazard, safety, software, system of systems, validation metrics.

I. INTRODUCTION

SOFTWARE has a growing, even predominant role in automating the decisions taken in safety-critical systems, including large-scale weapon systems (e.g., command of missile launchers via an engage-on-remote capability). Current and future generations of military capabilities require dependable systems of systems (SoSs) that integrate multiple software applications along with many physical systems. SoS must address all safety hazards before deploying the final system. One approach to risk management is Hazard Analysis (HA). HA techniques for SoS must address both the size and complexity of a SoS, and include defined practices that allow an engineer to keep pace with the evolution of a SoS over its lifecycle. These practices must cover the full scope of a SoS; they support both design and analysis to clarify what risks and hazards in a SoS may have been

overlooked. HA answers the question for a SoS, “What are the known and possible residual hazards in this system?”

Hazard Analysis, as applied in this paper, also plays an important role in the practice of Software System Safety; this practice depends on a set of management and engineering activities from the System Safety and Software Engineering domains. The intent is to identify, analyze, design, and track software mitigation and control of hazards and hazardous functions [1]. Effective analysis of the safety of software requires the engineer to work within the system context in which the software is executing. Therefore, the Software System Safety Engineering process typically starts with the System Safety Engineering activities to identify potential hazards at the System Engineering level. In this case, potential hazards and safety-critical functions are traced through high-level design and architecture, and ends with validation and verification (V&V) of software safety features required for controlling the hazard causal factors. (Readers can refer to [2] for definitions of error, failure, mishap, hazard, hazard causal factor and risk.)

In [3], Weaver identified the sufficiency of hazard identification and the adequacy of hazard analysis to identify software’s role in causing these hazards as two important considerations in constructing a safety case. He also advocated the use of traceability from the derived software safety requirements to the identified system hazards as an indication of the completeness of the set of software safety requirements. Measuring the affects of software on system safety is a relatively unexplored aspect of software engineering. In [4], Basili *et al.* presented an approach for developing software safety measures to gain early insights into potential safety problems and risks. While the metrics suggested in [4] cannot provide proof or validation of the software safety requirements, they can be used to identify potential weakness in the software system safety process and an associated likelihood that the system will not be safe.

This paper addresses the need for management to assess the adequacy of the software safety engineering process. It focuses on the contribution of software toward the safety afforded by SoSs and builds upon Weaver’s and Basili’s work by introducing a means for measuring the sufficiency of software safety requirements with a set of metrics derived from the hazard identification, hazard analysis, and requirements traceability artifacts. We present a Validation Metrics Framework for management to gauge the sufficiency of the software safety requirements early in the software development process. The framework describes a validation process in which the software safety engineering team acts as an advocate for safety on behalf of the stakeholders (Fig. 1). It complements the traditional methods of

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J. B. Michael and M.-T. Shing are with the Department of Computer Science, Naval Postgraduate School, Monterey, CA 93943, USA (e-mail: bmichael@nps.edu; shing@nps.edu).

K. J. Cruickshank and P. J. Redmond are with the Royal Australian Air Force, RAAF Base Williams, Laverton, Vic., 3027 Australia (e-mail: kristian.cruickshank@defence.gov.au; patrick.redmond@defence.gov.au).

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A Validation Metrics Framework For Safety Critical Software Intensive Systems

Larry Jones



A Validation Metrics Framework For Safety Critical Software Intensive Systems:

A Validation Metrics Framework for Safety-critical Software-intensive Systems Kristian John Cruickshank, 2009 Validation of safety critical software requirements is a difficult and frequently misunderstood task It answers the question of are we building the right product and is essential to Software Engineering However validation is often confused with verification activities or simply left as a final tick in the box just prior to delivery Current models for validation cannot satisfy the unique aspects of safety critical software where building the right safety product is paramount Software safety requires a new model for validation of safety requirements by proxy The need for a proxy model becomes evident in the software safety process where customer input for safety is reduced to the requirement of a safe system This thesis defines a new proactive model for validation of safety critical software requirements Continuous assessment of validity of safety requirements is indicated by metrics as part of the Validation Metrics Framework The generic framework combines the Goal Question Metric Approach with Goal Structuring Notation and then specializes in validation of safety critical software The metrics are measurements of safety products typical to safety critical software development programs A fictitious case study of a Rapid Action Surface to Air Missile is used to apply the framework identifying the benefits of a proactive indicative validation technique utilizing a metrics framework *Requirements Engineering: Foundation for Software Quality* Eric Knauss, Michael

Goedicke, 2019-03-11 This book constitutes the proceedings of the 25th International Working Conference on Requirements Engineering Foundation for Software Quality REFSQ 2019 held in Essen Germany in March 2019 The 13 full papers and 9 short papers in this volume were carefully reviewed and selected from 66 submissions The papers were organized in topical sections named Automated Analysis Making Sense of Requirements Tracelink Quality Requirements Management Research Previews From Vision to Specification Automated Analysis Research Previews Requirements Monitoring Open Source Managing Requirements Knowledge at a Large Scale in Situ Walkthroughs Research previews **Verification and**

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Reports, 1994 *Networking and Information Technology Research and Development* National Science and Technology Council (U.S.). Subcommittee on Networking and Information Technology Research and Development, 2006 **Automated People Movers**, 1997 Computer & Control Abstracts, 1996 Programming Atmel Microcontrollers Richard

Johnson,2025-06-15 *Programming Atmel Microcontrollers* provides a comprehensive roadmap for embedded engineers developers and advanced students seeking to master the architecture toolchains and firmware design patterns behind Atmel's renowned AVR and ARM Cortex M microcontroller families. The book details the internal workings of these microcontrollers covering core architectures memory organization peripheral systems and the intricacies of clock power and interrupt management equipping readers with the foundational knowledge to navigate both 8 bit and 32 bit platforms with confidence. With practical insight the book delves into firmware development techniques and modern toolchains guiding readers through project organization debugging strategies and simulation workflows. It explores advanced programming techniques including direct register access optimized assembly routines and performance tuning for robust energy efficient firmware. The coverage extends to efficient peripheral controls from GPIO and timers to complex protocols such as CAN LIN DMA and industrial bus interfaces ensuring readers can harness every hardware capability available. Employing best practices from modular software architecture to security by design the book addresses not only technical implementation but also the demands of testing validation and regulatory compliance for critical applications. Real world case studies spanning industrial controls automotive networks IoT gateways and medical devices underscore the practical relevance of Atmel microcontrollers in a connected world positioning this guide as an indispensable resource for building scalable reliable and secure embedded systems.

Software Engineering for Self-Adaptive Systems Rogério de Lemos,Holger Giese,Hausi A. Müller,Mary Shaw,2013-01-03 Although the self adaptability of systems has been studied in a wide range of disciplines from biology to robotics only recently has the software engineering community recognized its key role in enabling the development of self adaptive systems that are able to adapt to internal faults changing requirements and evolving environments. The 15 carefully reviewed papers included in this state of the art survey were presented at the International Seminar on Software Engineering for Self Adaptive Systems held in Dagstuhl Castle Germany in October 2010. Continuing the course of the first book of the series on Software Engineering for Self Adaptive Systems the collection of papers in this second volume comprises a research roadmap accompanied by four elaborating working group papers. Next there are two parts with three papers each entitled Requirements and Policies and Design Issues. Part four of the book contains four papers covering a wide range of Applications Defense Issues , The GEC Journal of Research ,1995

Department of Defense Authorization for Appropriations for Fiscal Year 1994 and the Future Years Defense Program United States. Congress. Senate. Committee on Armed Services,1994 Fusion and Integration of Clouds, Edges, and Devices Junlong Zhou,Kun Cao,Jin Sun,Keqin Li,2024-12-06 This book provides an in depth examination of recent research advances in cloud edge end computing covering theory technologies architectures methods applications and future research directions. It aims to present state of the art models and optimization methods for fusing and integrating clouds edges and devices. Cloud edge end computing provides users with low latency high reliability and cost effective services through the

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Proceedings, 11th IEEE International Conference and Workshop on the Engineering of Computer-Based Systems Vaclav Dvorak, Miroslav Sveda, 2004

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