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 guides 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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A Validation Metrics Framework For Safety Critical Software Intensive Systems

Roman Obermaisser,Yunmook Nah,Peter Puschner,Franz J. Rammig

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 safet 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 Validation of Modern Software-intensive Systems G. Gordon Schulmeyer,Garth R. MacKenzie,2000 PLEASE PROVIDE COURSE INFORMATION PLEASE PROVIDE **Software Technologies for Embedded and Ubiquitous Systems** Roman Obermaisser,Yunmook Nah,Peter Puschner,Franz J. Rammig,2007-09-17 This book constitutes the thoroughly refereed post proceedings of the 5th IFIP WG 10 2 International Workshop on Software Technologies for Future Embedded and Ubiquitous Systems SEUS 2007 held in conjunction with ISORC 2007 the 10th IEEE International Symposium on Object component service oriented Real time Distributed Computing Coverage includes ubiquitous computing frameworks validation of embedded and ubiquitous systems and ubiquitous computing applications

Scientific and Technical Aerospace 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 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 fusion and integration of clouds edges and devices As a result it is now widely used in various application scenarios The book introduces the background and fundamental concepts of clouds edges and devices and details the evolution concepts enabling technologies architectures and implementations of cloud edge end computing It also examines different types of cloud edge end orchestrated systems and applications and discusses advanced performance modeling approaches as well as the latest research on offloading and scheduling policies It also covers resource management methods for optimizing application performance on cloud edge end orchestrated systems The intended readers of this book are researchers undergraduate and graduate students and engineers interested in cloud computing edge computing and the Internet of Things The knowledge of this book will enrich our readers to be at the forefront of cloud edge end computing Software Engineering Trends and Techniques in Intelligent Systems Radek Silhavy,Petr Silhavy,Zdenka Prokopova,Roman Senkerik,Zuzana Kominkova Oplatkova,2017-04-07 This book presents new approaches and methods to solve real world problems as well as exploratory research describing novel approaches in the field of software engineering and intelligent systems It particularly focuses on modern trends in selected fields of interest introducing new algorithms methods and application of intelligent systems in software engineering The book constitutes the refereed proceedings of the Software Engineering Trends and Techniques in Intelligent Systems Section of the 6th Computer Science On line Conference 2017 CSOC 2017 held in April 2017 **Redundancy and Reliability in Spacecraft Safety Systems: Principles, Architectures, and Applications** Edenilson Brandl, Space exploration represents humanity s boldest endeavor pushing the limits of technology science and courage This work delves into the critical systems and methodologies that ensure the safety and reliability of spacecraft operating in the unforgiving environment of space By examining historical developments state of the art technologies and innovative strategies this book seeks to illuminate the intricate balance required between ambition and safety It is designed for engineers researchers and enthusiasts who aspire to understand and advance the principles that keep spacecraft operational and missions successful **Government Reports Annual Index** ,1994 Programming MQL5 for Algorithmic Trading Richard Johnson,2025-05-27 Programming MQL5 for Algorithmic Trading Programming MQL5 for Algorithmic Trading is a comprehensive and authoritative guide for developers quantitative analysts and trading professionals seeking to master the art and science of automated trading on the MetaTrader 5 platform This meticulously structured book covers the entire spectrum of MQL5 programming from mastering language foundations object oriented design and memory management to leveraging MetaEditor s powerful features for crafting robust maintainable trading systems With detailed explorations of the MetaTrader 5 system internals the text empowers readers with a solid understanding of terminal architecture market data handling order execution and integration with libraries and DLLs The book delves deeply into advanced topics crucial for competitive algorithmic trading including real time data acquisition multitimeframe and custom symbol analysis and efficient data processing for both backtesting and live

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