Guest Editorial
Celebrating 75 Years of Excellence: The Enduring Legacy and Future Outlook of the IEEE Reliability Society

SEVENTY-FIVE years ago, visionaries in the field of reliability engineering came together to establish the IEEE Reliability Society, marking the commencement of a remarkable journey toward enhancing the dependability, resilience, and security of technological systems. As we celebrate this significant milestone, it is an opportune moment to reflect on the society's illustrious history, achievements, and the enduring impact it has had on the world of technology.

Founded in 1947, the IEEE Reliability Society emerged in response to the growing recognition of the pivotal role reliability plays in ensuring the success of complex systems. The society was established with the mission to advance the theory and practice of reliability engineering, providing a platform for professionals, researchers, and enthusiasts to collaborate and share their expertise.

Over the past seven and a half decades, the IEEE Reliability Society has evolved into a global hub for knowledge exchange and innovation. The society has consistently pioneered advancements in reliability methodologies, tools, and standards, contributing significantly to the robustness of various industries, including aerospace, telecommunications, integrated circuits, hardware, software, networking, manufacturing, and more.

Key achievements include the following.

1) *Publications and journals:* The IEEE Reliability Society has been at the forefront of disseminating cutting-edge research through its publications and journals. These resources have become invaluable references for engineers and researchers striving to enhance the reliability, security, and availability of systems.
2) *Conferences and symposia:* The society has organized and sponsored numerous conferences and symposia, providing a platform for experts to discuss the latest developments, share best practices, and explore emerging trends in reliability engineering.
3) *Professional development:* Through workshops, webinars, and training programs, the IEEE Reliability Society has played a crucial role in enhancing the professional development of its members. The society's commitment to education has empowered countless individuals to tackle the challenges of reliability engineering head-on.
4) *Collaborations and partnerships:* By establishing collaborations with other IEEE societies, industry partners, and academic institutions, the Reliability Society has fostered a culture of interdisciplinary collaboration, driving innovation and advancements in reliability engineering.

As we celebrate this momentous 75th anniversary, the IEEE Reliability Society remains dedicated to its mission of advancing the field of reliability engineering. With the rapid evolution of technology, the society is poised to tackle new challenges, embracing emerging trends, such as artificial intelligence (AI), machine learning, autonomous driving, the Internet of Things, cyber trust, resilience, and security.

The Future holds the following.

1) *Integration of emerging technologies:* The IEEE Reliability Society will continue to explore the integration of emerging technologies to address the evolving landscape of reliability challenges.
2) *Global outreach:* Fostering a global community of reliability professionals, the society aims to expand its outreach, promoting knowledge-sharing and collaboration on an international scale.
3) *Youth engagement:* Encouraging the involvement of young professionals and students, the society will focus on nurturing the next generation of reliability engineers through outreach programs, distinguished speakers, and educational initiatives.

As we applaud the achievements of the past 75 years, the IEEE Reliability Society stands as a beacon of excellence in the realm of reliability engineering. The society's commitment to innovation, education, and collaboration has not only shaped the past but will undoubtedly continue to influence the future of technology and its reliability for many years to come. Here's to 75 years of resilience, progress, and the unwavering pursuit of reliability excellence!

In this Special Section, we will explore the concepts of timelessness and timeliness in reliability engineering, which, respectively, underscore the enduring principles and contemporary relevance of the field.

1) *Timelessness:*
   a) *Foundational principles:* Reliability engineering is built on timeless principles that have remained relevant throughout the evolution of technology. Concepts such

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as failure analysis, system robustness, and risk management, form the bedrock of reliability practices and continue to guide engineers in designing dependable systems.

b) *Mathematical models:* The mathematical models used in reliability engineering, such as reliability block diagrams and fault tree analysis, have stood the test of time. These tools provide engineers with a structured approach to assess and improve system reliability, regardless of the specific industry or technology involved.

2) *Timeliness:*

a) *Adaptation to technological advances:* Reliability engineering adapts to the changing technological landscape. As new technologies emerge, reliability practices evolve to address the unique challenges they present. For example, the integration of AI and machine learning in systems requires novel approaches to reliability assessment and maintenance strategies.

b) *Industry-specific applications:* Reliability engineering demonstrates timeliness by tailoring its methodologies to the specific needs of different industries. Whether it is aerospace, healthcare, telecommunications, or energy, reliability practices are customized to address the unique demands and risks associated with each sector.

c) *Continuous improvement:* The timeliness of reliability engineering is reflected in its commitment to continuous improvement. Engineers regularly update methodologies, incorporate feedback from real-world applications, and embrace new tools and technologies to enhance system reliability in the face of evolving challenges.

In essence, the timelessness of reliability engineering underscores its enduring principles and universal applicability, while its timeliness emphasizes the field's adaptability to contemporary technological advancements and industry-specific requirements. Achieving a balance between these aspects ensures that reliability engineering remains a robust and relevant discipline in safeguarding the dependability of modern systems.

Research in the field of reliability has evolved considerably since the topic was first envisioned as a topic of research. As the IEEE Reliability Society approaches its 75th anniversary, it is important to take stock in the research topics and developments that have led us to this day. This society, and its transactions which has existed almost as long, has been a host to the research that the members of this great community have furthered. Some of those contributing experts have graciously contributed works that highlight important reliability topics and research that represent the classical core of reliability.

This Special Section covers both *classical reliability topics* and *emerging subjects*. It commences with classical reliability topics, then transitions to address emerging areas. First, Phil Laplante provides an overview of the ten most cited articles and a history of the editorship of IEEE TRANSACTIONS ON RELIABILITY in two separate articles [A1], [A2]. Following that, Kishor Trivedi reviews the treatment of the foundational topic of reliability and availability assessment [A3]. This article offers a quick survey of the topic, serving as a launch point for the rest of the section.

The next article in this section focuses on the application of probabilistic physics of failure to reliability engineering by Mohammad Modarres [A4]. This article surveys the foundational topic of how physical failure models apply in the field of reliability engineering.

With an easy transition to the next and closely related topic of accelerated life tests with step and varying stress, Wayne Nelson provides a comprehensive survey of the fundamentals and the future of this important topic [A5].

Andrew Jardine takes us next into the related topic of vibration monitoring in the industry, providing a historical perspective that brings us to the present [A6]. He discusses related topics, such as condition-based maintenance, in an interesting and unique presentation.

Next, Haitao Liao provides a more extensive treatment of the topic of accelerated testing and smart maintenance, discussing the history and future of this important classical topic [A7]. This article covers reliability prediction and explores how maintenance has evolved from routine to failure to smart maintenance.

Transitioning seamlessly to mathematical maintenance theory, Hoang Pham leads us through the topic chronologically and presents a view of the future where sensors and AI bring maintenance optimization further [A8].

The next closely related topic is briefly presented by Enrico Zio on reliability prediction and predictive maintenance, with a nod to the newer topic of prognostics and health management (PHM) [A9]. Although PHM is a relatively recent development, its foundation is classical, and the topic has matured for more than a decade already.

Next, Elsayed A. Elsayed, Yao Cheng, and Haitao Liao provide an in-depth article on reliability and resilience, taking us back to foundational topics [A10]. This longer article covers resiliency as a property of materials, includes quantitative metrics, and paints a picture of the future of this topic, addressing important problems to be resolved.

Kailash Kapur then takes us beyond binary states and into fuzzy sets and customer-focused models [A11]. The article includes valuable references on the topic, helping the reader gain a solid foundational understanding of the concepts.

Following that, David Coit surveys system reliability optimization in a friendly, introductory way, providing a discussion of important references on the topic [A12]. Enrico Zio returns to offer his complementary perspective on reliability optimization, referencing work that he collaborated on with David Coit [A13].

Gregory Levitin and Liudong Xing contribute an article on mission-aborting policies and multiattempt missions, covering the history and extensions of this important systems topic [A14].

The next article by Ning Zhang et al. summarizes the reliability equivalent criteria, the modeling of the reliability function, and the solving strategies for the concept of capacity credit of generators, proposing four aspects of future work [A15].

Zhaojun Steven Li provides a review of resilience metrics and modeling methods for cyber-physical power systems [A16].

Finally, we return to where we started in a sense with Kishor Trivedi again, but this time on the topic of software fault tolerance [A17]. While software reliability is not as old of a topic as some of these others, it is still a mature and classical subject with decades of research to present. This lengthy article covers bugs, forms of diversity, and an interesting example.

This set of classical reliability topics does not cover all aspects of reliability, certainly. Fundamental topics are acknowledged, but many important applications of reliability research in fields such as infrastructure, communications, power systems, and healthcare, for example, are topics we encourage you all to explore. In those applications, you will see how reliability research has been at the heart of successful technology, which has bettered humanity.

The second part of this Special Section focuses on the emerging topics of reliability engineering. In the face of evolving cyber threats and changing technologies, the first article, coauthored by nine experts, investigates the challenges, current progress, and future trends of rapidly converging technologies [A18]. This includes practices and applications of cyber trust and security, AI-empowered autonomous driving systems, modern mobile networks, blockchains and distributed ledger technologies, prognostic and health management, integrated circuits and hardware, and enterprise cybersecurity and threat hunting.

In the next article, Rick Kuhn addresses the challenges of assured autonomy, summarizing some recent novel approaches to the problem of verification, testing, and assurance of autonomous systems, which also have applications in explainable AI [A19].

The competition between hackers and defenders is likened to the game of spear and shield in cybersecurity. In light of the fast evolution of hacking techniques, Shanhsin Lee et al. introduce in the next article the current state, approaches, and challenges from both attackers and defenders' perspectives to illustrate the gap between lab evaluation and real-world practice [A20]. Finally, research opportunities for the next era of the game of spear and shield are proposed.

In response to the recent dramatic increase in cybersecurity threats, Mengru Tsai et al. address the challenges of handling cyber threats in the next article [A21]. The article proposes strategies, implementation details, and limitations of Zero Trust Architecture, aiming to shed light on its effectiveness and applicability in mitigating cybersecurity risks.

This set of emerging reliability topics only covers the future outlook of some aspects of reliability engineering, exemplified by a few research areas. Reliability, which one could say is the science of turning research into viable developments, is at the heart of the mission of the IEEE. As you read these classical tutorial works, you may see, as we do, that all these topics are foundational to engineering, the application of technology, and the mission of the IEEE in all contexts we encounter in our daily life. One could say these topics are foundational to life as we know it today.

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APPENDIX: RELATED ARTICLES

[A1] P. A. Laplante, "The ten most cited papers from IEEE Transactions on Reliability," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 8–10, Mar. 2024.

[A2] P. A. Laplante, "A history of editorship of the *IEEE Transactions on Reliability*," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 11–12, Mar. 2024.

[A3] K. Trivedi, "Reliability and availability assessment," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 13–14, Mar. 2024.

[A4] M. Modarres, "Probabilistic physics of failure concept and its application in reliability engineering," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 15–16, Mar. 2024.

[A5] W. B. Nelson, "Advances in accelerated life tests with step and varying stress," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 17–26, Mar. 2024.

[A6] A. K. S. Jardine, "Vibration monitoring in industry: Then and now," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 27–28, Mar. 2024.

[A7] H. Liao, "Accelerated testing and smart maintenance: History and future," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 29–33, Mar. 2024.

[A8] H. Pham, "Mathematical maintenance theory: A historical perspective," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 34–36, Mar. 2024.

[A9] E. Zio, "Prognostics and health management methods for reliability prediction and predictive maintenance," *IEEE Trans. Rel.*, vol. 73, no. 1, p. 37, Mar. 2024.

[A10] Y. Cheng, H. Liao, and E. A. Elsayed, "From reliability to resilience: More than just taking one step further," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 38–42, Mar. 2024.

[A11] K. C. Kapur, "Advances beyond binary states [success/failure] to multi-state and fuzzy sets and customer-focused cumulative experience dynamic models," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 43–44, Mar. 2024.

[A12] D. W. Coit, "History of system reliability optimization," *IEEE Trans. Rel.*, vol. 73, no. 1, p. 45, Mar. 2024.

[A13] E. Zio, "Reliability optimization," *IEEE Trans. Rel.*, vol. 73, no. 1, p. 46, Mar. 2024.

[A14] G. Levitin and L. Xing, "Mission aborting policies and multiattempt missions," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 47–48, Mar. 2024.

[A15] N. Zhang, Y. Yu, C. Fang, Y. Su, and C. Kang, "Power system adequacy with variable resources: A capacity credit perspective," *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 49–54, Mar. 2024.

[A16] Z. S. Li, G. Wu, R. Cassandro, and H. Wang, “A review of resilience metrics and modeling methods for cyber-physical power systems (CPPS),” *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 55–62, Mar. 2024.

[A17] K. S. Trivedi, M. Grottke, and J. A. Lopez, “Rethinking software fault tolerance,” *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 63–68, Mar. 2024.

[A18] S. W. Shieh, J. Voas, P. Laplante, J. Rupe, C. Hansen, Y.-S. Wu, Y.-T. Chen, C.-Y. Li, and K.-C. Wu, “Reliability engineering in a time of rapidly converging technologies,” *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 69–78, Mar. 2024.

[A19] D. R. Kuhn, “Challenges of assured autonomy,” *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 79–80, Mar. 2024.

[A20] S. Lee, M. Tsai, and S. W. Shieh, “The game of spear and shield in next era of cybersecurity,” *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 81–88, Mar. 2024.

[A21] M. Tsai, S. Lee, and S. W. Shieh, “Strategy for implementing of zero trust architecture,” *IEEE Trans. Rel.*, vol. 73, no. 1, pp. 89–96, Mar. 2024.