NAVIGATING QUANTUM TECHNOLOGIES FOR UNDERSEA NUCLEAR RISK REDUCTION: PRINCIPLES AND PERCEPTIONS

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Quantum technology is expected to transform numerous aspects of international security. States with advanced quantum capabilities will enjoy revolutionary military innovation through, for instance, quantum computing, quantum communication, and quantum sensing.[1] Therefore, it is hardly surprising that such technology has now become part of national strategies around the world. Quantum technology also promises great advantages for civilian uses.

The Asia-Pacific is currently witnessing such a trend: substantial investment in quantum technology. Among the key powers in the region, such as Australia, China, India, Japan, South Korea, and the United States, significant financial resources are being allocated for both ongoing development and long-term public spending strategy through various government initiatives, international collaborations, the establishment of research institutions, and the construction of specialised facilities. These policies, outlined in official government documents, often exhibit the intention to lead in quantum technological advancements, citing significant contribution to the advancement of the country.

While theoretically, the science itself is already labelled as the "next revolution," the practical application of such technology might take some time to catch up with this label. However, it is essential to recognise that this should not be a reason to disregard the conversation. The "dual-use" applications of quantum technology, its nascent nature, and the revolutionary promises make certain the race for its supremacy, but do not guarantee its implications on the strategic front.

We have some ideas about how such technology might influence strategic calculations, but a deeper assessment needs to be made in order to navigate this technology in the direction of stability as quantum technology, particularly in military applications, is likely to reshape not only the landscape of operational affairs but also the strategic behaviour and threat perceptions among states. What, then, are the implications not only of the technical applications of quantum technology in the military undersea domain, but also of how such technologies might mediate and influence escalation risks, perceptions of deterrence logic, and strategic decision-making? Against this uncertainty, what possible frameworks could be developed to help navigate these emerging challenges and, more importantly, establish preventive measures to reduce the risk of a worst-case scenario arising from the intersection of quantum technology and nuclear escalation?

In order to answer these questions, this paper first addresses these concerns by providing a brief overview of investment in quantum technology and research by the key powers in the region: including Australia, China, India, Japan, South Korea, and the United States. The chapter then

[1] Michal Krelina, "Quantum Technology for Military Applications," *EPJ Quantum Technology* 8, no. 1 (2021): 24, https://doi.org/10.1140/epjqt/s40507-021-00113-y.

assesses two strategic implications of quantum technology applications in the undersea nuclear domain. First, a technical assessment of the current state of development, including the potential for and applications of such technologies on the operational front, and second, a strategic behavioural assessment examining how such applications could influence strategic thinking, including the possible threat perceptions among states. The paper concludes by proposing the "SIREN" framework as a policy recommendation.

Quantum investment in the Asia-Pacific: Trends and strategy

Australia, China, India, Japan, South Korea, and the United States have all committed substantial resources towards their respective national quantum strategies. Any analysis of strategic investments in quantum technology must account for its inherently dual-use nature as states rarely attribute their quantum research directly to military applications. Here are some of the interesting quantum activities in the Indo-Pacific.

Australia

- Australia's engagement in quantum technology is anchored by its *National Quantum Strategy*.[2] Released in 2023, the Strategy addresses key approaches, including investing in quantum research and industry, creating pipelines for investment in industry-ready quantum technologies, championing responsible innovation, and ensuring that the growth of Australia's quantum industry supports economic prosperity while safeguarding our national interests.
- Quantum Technology is named as one of the six key capabilities in the 2026 Defence Innovation, Science and Technology Strategy.[3] In this document, quantum technology is expected to provide "secure navigation and timing in GPS-denied environments, and advanced systems to counter drones and protect Defence personnel and infrastructure." In 2025, four Australian-developed quantum technology clocks have been successfully trialled in the United States as part of Australia's efforts to advance AUKUS Pillar II capabilities, supported by a $2.7 million investment from the Albanese Government.[4]

China

- As early as 2006, China has been interested in exploring quantum technology, particularly communications and networks. The National 13th Five-Year Plan for S&T Innovation, during its formation in 2015, had already captured the need for and cited quantum

[2] Australian Department of Industry, Science and Resources. "National Quantum Strategy," May 3, 2023, https://www.industry.gov.au/publications/national-quantum-strategy.

[3] Australian Minister for Defence, "Launch of the 2026 Defence Innovation, Science and Technology Strategy," Australian Government, August 4, 2026, https://www.minister.defence.gov.au/media-releases/2026-08-04/launch-2026-defence-innovation-science-technology-strategy.

[4] Australian Minister for Defence and Australian Minister for Pacific Island Affairs, "World-Leading Australian Quantum Clocks Successfully Trialled under AUKUS Pillar II," Australian Government, November 4, 2025, https://www.minister.defence.gov.au/media-releases/2025-11-04/world-leading-australian-quantum-clocks-successfully-trialled-under-aukus-pillar-ii.

communications as having a crucial role in China's strategic objectives. Furthermore, in 2020, President Xi also highlighted that the country should seek to "cultivate strategic emerging industries such as quantum communications."[5]

- In 2016, China has invested an estimated $15 billion or more in quantum technologies and has seen productive output as the country developed the world's first quantum satellite that year.[6] In 2017, Beijing also established the "world's first trunk line for secure quantum telecommunications," connected to the quantum satellite, and spanning approximately 2,000 kilometres.[7]
- Investment in quantum technologies has continued to grow in China. Beijing announced that the technology is one of the key priorities for research under the new *2030 Cyber Industry Plan*, showing that the country is collaborating quantum technology applications in supporting broader areas of technological development.[8]

India

- In 2023, the Union Cabinet approved the National Quantum Mission (NQM) budgeting the total cost of INR 60.0365 billion. This 2023–2030 quantum strategy aims to cover four thematic domains: quantum computing, quantum communication, quantum sensing & metrology, and quantum materials & devices.[9]
- On the military front, for example, Indian Army has established the Quantum Lab at Military College of Telecommunication Engineering in 2021 citing the aims to manoeuvre "into next generation communication and transform the current system of cryptography in the Indian Armed Forces to Post Quantum Cryptography (PQC)." Key research areas include quantum key distribution, quantum communication, quantum computing, and post-quantum cryptography.[10]

Japan

- In 2025, the Japanese government announced the allocation of around $7.4 billion in funding for quantum investment, citing 2025 as the "first year of quantum industrialisation"

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[5] Ciel Qi, "China's Quantum Ambitions: A Multi-Decade Focus on Quantum Communications," *Yale Journal of International Affairs* 19, no. 1 (2023), https://www.yalejournal.org/publications/chinas-quantum-ambitions.
[6] Entangled Future, "China National Quantum Strategy," accessed October 6, 2026, https://entangledfuture.com/government/china-quantum-strategy/. See also, BBC, "China Launches Quantum-Enabled Satellite Micius,"*BBC*, August 16, 2016, https://www.bbc.com/news/world-asia-china-37091833.
[7] Xinhua, "China Opens 2,000-Km Quantum Communication Line," The State Council Information Office, the People's Republic of China, September 30, 2017, http://english.scio.gov.cn/2017-09/30/content_41671118.htm.
[8] Matt Swayne, "China Puts Quantum Technology among Priorities in New 2030 Cyber Industry Plan." The Quantum Insider, August 24, 2026, https://thequantuminsider.com/2026/08/24/china-puts-quantum-technology-among-priorities-in-new-2030-cyber-industry-plan/.
[9] Indian Department of Science & Technology, "National Quantum Mission (NQM)," accessed October 6, 2026, https://dst.gov.in/national-quantum-mission-nqm.
[10] Press Information Bureau Delhi, "Indian Army Establishes Quantum Laboratory at Mhow (MP)," Indian Ministry of Defence, December 29, 2021, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1786012.

and a "pre-emptive, high-stakes intervention" aimed at achieving global leadership in quantum technology as part of the nation's strategic interests, which began in 2020.[11]

- On research front, for instance, the RIKEN Center for Quantum Computing (RQC) was established in 2021 as part of Japan's national quantum-information strategy focusing on researches in areas including "quantum information, as well as research targeted at creating quantum computing systems using superconducting qubits as well as other types of qubits." However, Tokyo's effort on quantum research can be traced back as early as 2001 when the Single Quantum Dynamics Research Group was established along with other laboratories researching in these areas throughout the years.[12]
- A quantum magnetic sensor is set to be integrated into an anti-submarine warfare (ASW) system supporting submarine detection capability. Tokyo's plan is to launch the "low-cost drones" equipped with the quantum sensor from the warship. This project is part of the 2027 fiscal budget request by the Ministry of Defense aiming to both further utilise the unmanned systems along with advancing risk reduction effort on the undersea domain.[13]

The Republic of Korea (ROK)

- In 2023, Ministry of Science and ICT announced the Quantum Science and Technology Strategy, which is the first-ever national strategy in this area of interest. The strategy aims to lead South Korea into becoming the "global hub for the quantum economy in 2035" through advancing quantum computers and sensors with "an integration with defense and advanced industries."[14]
- President Lee Jae Myung recently announced the "Seven Major SEED" initiative which listed out the "next-generation growth engines and core strategic national assets" which include a moon landing by 2030 all the way to the development of a domestic 100-qubit quantum computer by 2029.[15]
- The Korea Research Institute of Standards and Science (KRISS) is developing a quantum gravimeter for submarine applications, with a prototype reportedly targeted for deployment on an actual submarine by 2032. It seems like the group has already demonstrated

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[11] Pablo Valerio, "Quantum Sun Rises, Japan Gambit for Leadership," *EE Times*, June 30, 2025, https://www.eetimes.com/quantum-sun-rises-japan-gambit-for-leadership/.

[12] RIKEN, "RIKEN Center Is Focusing on Quantum Computing," July 21, 2021, https://www.riken.jp/en/news_pubs/news/2021/20210721_1/index.html.

[13] Aryan Singh, "Chinese Submarines Face a New Challenge: Japan's Low-Cost Drones with Quantum Sensors," *The Times of India*, September 16, 2026, https://timesofindia.indiatimes.com/defence/international/chinese-submarines-face-a-new-challenge-japans-low-cost-drones-with-quantum-sensors/articleshow/134277396.cms.

[14] ROK Ministry of Science and ICT, "Press Releases: In 2035, Korea Becoming the Global Hub for Quantum Economy," June 27, 2023, https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&nttSeqNo=828&searchOpt=ALL&bbsSeqNo=42&mId=4&mPid=2.

[15] Kyu-Seok Shim, "South Korea Unveils Future Technology Drivers, Targets Moon Landing By 2030," *Reuters*, August 12, 2026, https://www.reuters.com/world/asia-pacific/south-korea-unveils-future-technology-projects-targets-moon-landing-by-2030-2026-08-12/.

sensitivity at the laboratory level that is considered to be among the world's leading results.[16]

The United States

- The National Quantum Initiative Act, enacted in 2018, represents one of the first cornerstones in the national quantum strategy to propel quantum research and development. The bill serves as a legislation which "directs the President to implement a National Quantum Initiative Program to, among other things, establish the goals and priorities for a 10-year plan to accelerate the development of quantum information science and technology applications."[17]
- For the United States, quantum information science and technology (QIST) is the key term used throughout the country's quantum strategy. QIST encompasses five areas of focus: (1) quantum computing and quantum-centric supercomputing, (2) quantum communication, (3) quantum sensing, (4) quantum materials, and (5) quantum artificial intelligence (AI) and quantum data centres.[18]
- Congress has a positive record of passing numerous provisions regarding the development of technology, for example: "to execute a quantum technology research and development program in coordination with the private sector, international entities, and other government agencies." and "authorizes the Secretary of each military department to establish Quantum Information Science (QIS) Research Centers that may "engage with appropriate public and private sector organizations" to advance quantum research."[19]

Technological assessment: Quantum military application on undersea domain

Quantum technology is an emerging field rooted in the principles of quantum mechanics, which allows engineers and scientists to manipulate quantum states to achieve technological advancements. This technology can be utilised in several key military capabilities, including detection and navigation which hold the potential to revolutionise systems relevant to undersea deterrence efficiency and operational effectiveness, carrying direct implications for nuclear strategic calculation and escalation risks.

In regard to the undersea military domain, the widespread recognition of quantum technology's transformative possibilities is often mentioned as a contribution to concerns over the "Transparent Ocean" which include fears that advancements in quantum technology could lead to unprecedented levels of undersea surveillance and detection, thereby destabilising the existing submarine

[16] Byeongku Lee, "KRISS Develops Quantum Gravimeter to Guide Nuclear Submarines without Satellites," *DongA Science*, August 21, 2026, https://www.dongascience.com/en/news/79491.
[17] 115th Congress, "H.R.6227 - National Quantum Initiative Act," December 21, 2018, https://www.congress.gov/bill/115th-congress/house-bill/6227.
[18] Hideki Tomoshige and Phillip Singerman, "Progress toward Practical Areas of Quantum Technology," Center for Strategic and International Studies, July 15, 2025, https://www.csis.org/analysis/progress-toward-practical-areas-quantum-technology.
[19] Kelly M. Sayler, "Defense Primer: Quantum Technology," Congressional Research Service, May 12, 2026, https://www.congress.gov/crs-product/IF11836.

operations and nuclear deterrence regime.[20] As submarines' stealth and ability to hide in the vast ocean is crucial to the second-strike capability that is critical to nuclear deterrence, enhanced detection capabilities, enabled by quantum technologies, could jeopardise not only the operational concern but state's perception of their own security.

Quantum sensors – in particular – are poised to revolutionise underwater detection and object identification, enhancing the accuracy and reliability of tracking submarines. Quantum imaging further improves resolution for precise mapping of undersea objects, making it increasingly difficult for these strategic assets to remain undetected. If the survivability of these second-strike forces is compromised, the deterrence balance that has long prevented the use of nuclear weapons could be destabilised, leading to a more precarious strategic environment. Such anxiety could prompt the textbook security dilemma by provoking each country to enhance their own capabilities in response, potentially leading to a new and dangerous phase of arms competition. Quantum technology is also believed to significantly enhance other disruptive technologies, enabling other threats and perceptions in themselves, such as AI.

For the undersea domain, quantum technology is expected, among other things, to help enhance the detection, sensing, positioning, and navigating submarines and other ASW capabilities through various technological branches, including quantum magnetometers, gravity gradiometers, imaging, and so on. See Table 1 for an overview of key technologies.[21]

AREA OF APPLICATIONS	TECHNOLOGY	CAPABILITIES AND CHALLENGES
Detection	Quantum Magnetometers	• Enhanced sensitivity in detecting anomalies in magnetic fields. • Allowing more detection effectiveness and larger search area. • Considered a basic tool and the most applicable for the ASW. • Requires extreme cooling, therefore posing challenges for deployment.
	Quantum Gravity Gradiometers	• Enhanced ability to filter out "local vibration" when detecting anomalies in gravitational fields. • Can help environmental mapping and enhance situational awareness without using sonar.

[20] For further discussion of these concerns, see: Eli Sanchez, "Seeing through "Transparent Oceans": Emerging Technology, Submarine Vulnerability, and the Future of MAD," *International Security* 51, no. 1 (2026): 123-163, https://doi.org/10.1162/isec.a.417.

[21] The overview presented in this table, particularly on quantum magnetometers and quantum gravity gradiometers, is drawn primarily from these two sources, namely: Katarzyna Kubiak, "Quantum Technology and Submarine Near-Invulnerability," December 11, 2020, https://europeanleadershipnetwork.org/policy-brief/quantum-technology-and-submarine-near-invulnerability/. See also, Krelina, "Quantum Technology for Military Applications," 24.

AREA OF APPLICATIONS	TECHNOLOGY	CAPABILITIES AND CHALLENGES
		• This could enable deployment on moving vehicles. • Sensitivity issues limited the possibility of deployment on Space.
Navigation	Quantum Inertial navigation	• Allowing increasing inertial measurement accuracy and reduced reliance on Global Navigation Satellite Systems (GNSS) which is vulnerable to interference.[22] • Costly and still requires further trials to establish its reliability.[23]

TABLE 1. OVERVIEW OF KEY QUANTUM TECHNOLOGIES, THEIR UNDERSEA APPLICATIONS, AND CHALLENGES

Quantum threat perceptions and nuclear risk reduction navigator

Assessing what quantum technologies are used for in military applications in the undersea domain alone is not enough, as much literature and historical events will tell us: anticipation is of the essence and has played a significant role in strategic calculation, which dictates the direction of strategic peace and security.

In this case, quantum technology as a capability does not enter the strategic equation simply as a tactical weapons and advantages enabler, but also as a potential, an expectation, a factor that influences strategic perceptions and signalling. In this regard, the "fear and anxiety" serves as one of the key factors influencing states' threat perceptions.[24] For the undersea domain in particular, such fears could result in greater investment in ASW capabilities, both kinetic and non-kinetic, creating further possibilities for entanglement at the nuclear level.

The first possible source of fear is the loss of a first-mover advantage and the risk of falling behind in strategic competition. Although such competition may be difficult to win, the idea that inaction, or being surpassed, could result in significant disadvantages or even existential risks may create pressure for states to act in some capacity to prevent itself in such position. Such decisions may include prioritising heavy investment in quantum technology and, given its dual-use nature, it is reasonable to assume that other states may interpret such investments as an indication that a state is "arming up," leading states to fall into the textbook security dilemma based solely on assumptions about the others' intentions regarding such technology.

Another challenge can be drawn from a discussion of another closely related disruptive technology, AI. It is worth considering the possibility of decision-making anxiety at both the strategic and

[22] Nicola Loaring and Mark Moffett, "Quantum at Sea: The Future of Resilient Maritime Positioning," GPS World, September 9, 2026, https://www.gpsworld.com/quantum-at-sea-the-future-of-resilient-maritime-positioning/.
[23] Loaring and Moffett, "Quantum at Sea."
[24] TRT Research Center, "Threat Perception: Definition Meaning, and Why It Matters," accessed October 6, 2026, https://researchcentre.trtworld.com/dictionary/threat-perception/.

operational levels. This "Quantum Anxiety" reflects not only the aforementioned fear of losing a strategic advantage but also the sense of urgency and the compressed decision-making time.[25] If a state perceives its adversary to be possessing extremely advanced technology and believes that its own undersea capabilities are particularly vulnerable, it may feel pressure to take extreme measures to prevent itself from being attacked or its capabilities from being exposed right there and then. There is no way to predict the outcome. Unfortunately, the worst-case scenario could involve escalation at both the conventional and nuclear levels.

Amidst the growing concerns surrounding nuclear risk and the ongoing discussions among scholars and policy analysts, various potential pathways toward nuclear risk reduction are being explored. A particularly noteworthy contribution to this discourse is the research by Wilfred Wan, published by the United Nations Institute for Disarmament Research (UNIDIR), titled *Nuclear Risk Reduction: A Framework for Analysis*. In his study, Wan proposes a comprehensive framework for addressing the challenges associated with the potential use of nuclear weapons. He identifies four key areas of risk that require focused attention, as shown in Table 2.[26] In these areas, the key factors also include a variety of factors, including political, international relations, technological integration, and human psychology.

NUCLEAR RISKS	CHARACTERISTICS
Doctrinal Risk	This pertains to the risk associated with the use of nuclear weapons as outlined in official policies, which are often based on the concept of retaliatory strikes. These policies may include deliberate ambiguities that increase the uncertainty surrounding nuclear use.
Escalatory Risk	This risk is linked to the potential for nuclear weapons to be employed during periods of heightened tensions, ongoing conflicts, or crises. Escalation could occur as a result of misinterpretation, miscalculation, or the rapid deterioration of a situation.
Unauthorised Risk	This involves the risk of nuclear weapons being used without official sanction. Such scenarios might include rogue state actors or non-state entities gaining access to nuclear weapons, either through theft, loss, or the acquisition of crude nuclear devices.
Accidental Risk	This category addresses the potential for nuclear weapons to be used inadvertently due to human error, technical failures, or misunderstandings in communication.

TABLE 2. A BRIEF SUMMARY OF *NUCLEAR RISK REDUCTION: A FRAMEWORK FOR ANALYSIS* BY WILFRED WAN

[25] Natasha E. Bajema and John Gower, "Nuclear Decision-Making and Risk Reduction in an Era of Technological Complexity," Council on Strategic Risks, December 2022, https://councilonstrategicrisks.org/research/reports/nuclear-decision-making-and-risk-reduction-in-an-era-of-technological-complexity/.

[26] Wilfred Wan, *Nuclear Risk Reduction: A Framework for Analysis* (UNIDIR, 2019), https://unidir.org/files/publication/pdfs/nuclear-risk-reduction-a-framework-for-analysis-en-809.pdf.

Against the current trajectory of quantum technology, its potential military applications, and the associated risks of nuclear use in the undersea domain, it is essential to identify a pathway for action to manage and reduce these risks. Drawing on Wan's Nuclear Risk Reduction Framework and considering the nature of quantum technology, the most significant gap in the existing approach should first be addressed through collaboration and communication, given that the technology itself remains under development. Provided that the dual-use nature of quantum technology, it is essential to clearly communicate its intended applications to reduce the risk of misperception. Intentional communication regarding the purposes of quantum advancements and national limitations on their role in nuclear decision-making can help alleviate concerns related to deterrence strategies, thereby easing tensions and managing potential nuclear crises.

Proposed undersea nuclear risk reduction initiative: The SIREN framework

In the face of evolving global threats and technological advancements, the intersection of quantum technology and nuclear risk reduction presents both profound opportunities and significant challenges. A new proposed collaborative and incremental framework offers a structured approach to harnessing quantum innovations for enhancing nuclear stability and security.

This policy framework, which may also serve as an initiative in itself, focuses on five key phases: Strategy, Investigation, Reassurance, Evaluation, and Navigation (SIREN). By following this methodology, partnering states can work together to address crucial issues such as perceptions of undersea nuclear use, the strategic integration of quantum technology, and management of time-sensitive crisis communications.

S: Developing "Strategy"

First and foremost, the partnering states must collaboratively address two areas which are critical for quantum technology cooperation in this purpose: perceptions regarding undersea nuclear use and the strategic approaches to nuclear risk reduction. Note that it is essential for these states to negotiate the extent of their collaboration, given that quantum technology often involves sensitive information that states may be reluctant to share. This undertaking will present significant challenges, but it is not insurmountable. Partners should keep the objective of "nuclear risk reduction" at the forefront of their discussions. This focus will contribute to strategic stability among all stakeholders and provide mutual benefits to all parties involved.

The process will require careful, step-by-step progression. For example, states might want to begin by establishing a shared working group to address the area of questions including the concerns over the technological application and potential scenario of misinterpretation and threat perceptions. This incremental approach will serve as a valuable pathway for further dialogues along with building trust in the process. The key to this stage is fostering open communication and understanding among the participating states. Initial dialogues can be informal, evolving into more structured and formal discussions as needed. The expected outcome of this stage should be a document or study that outlines the perceptions of undersea nuclear use and the strategic visions for nuclear risk reduction from the perspective of the states involved. This document should

identify common purposes, mutual understandings, and goals. It may also subtly incorporate discussions on the application of quantum technology as part of the broader strategy.

I: "Investigate" the area of potential quantum application

The investigation phase of the initiative centres on the collaborative exploration and identification of specific areas where quantum technology can be effectively leveraged to enhance nuclear risk reduction efforts. This phase builds upon the insights and findings from the preceding document or study. A key focus should be on "Quantum ISTAR" which encompasses Quantum Sensing, Quantum Communication, and Quantum Computing, as a primary area for initial collaboration.[27] During this phase, it is essential to concentrate on investments and activities related to scientific research, policy research projects, and war game simulations. The overarching objective is to ensure that investments in quantum technology are strategically aligned with and actively contribute to nuclear risk reduction efforts. The central question that both policymakers and technical professionals including quantum scientists and engineers must address collaboratively is: "How can quantum technology be applied to support nuclear risk reduction?" The answer to this question will vary depending on the threat perceptions and risk reduction strategies outlined in the strategic document or study.

While this stage will primarily demand significant expertise from technical professionals, including considerations of the technology's level of advancement, it is not their sole responsibility. Policymakers must also gain an understanding of the technology's potential applications, challenges, and limitations to effectively communicate and promote reassurance in the subsequent phase.

R: "Reassuring" the intention of the quantum investment

Reassurance is a crucial component in clearly communicating the peaceful intentions behind the nuclear risk reduction initiative. To achieve this, it is essential for states to create, publish, and disseminate an official communiqué that articulates the initiative's objectives with a particular emphasis on nuclear risk reduction. Each initiative or activity undertaken within this framework should explicitly demonstrate how it contributes to this overarching goal of avoiding the misperception which may lead to nuclear escalation.

The communiqué should underscore that there is an effort dedicated to risk reduction and stability dialogue, ensuring the direction of the quantum technology investment, activities, and applications. The ultimate objective is to create a sense of reassurance as both a pathway to strengthened deterrence and future global security collaboration, especially in other disruptive technology arena as well.

The purpose of this communication strategy is to prioritise the "nuclear risk reduction" objective by highlighting the primary goal and purpose of the activities. This approach aims to build trust

[27] Ajey Lele, *Quantum Technologies and Military Strategy* (Springer Nature, 2021).

and enhance predictability among stakeholders, addressing doctrinal concerns and assessing their potential relevance and risks. Intentional messages should communicate, as clear as they could that although the quantum technology is being invested, states have little to no willingness of using it in an offensive character, along with signalling the intention to mitigate the potential escalation through this initiative/policy framework. By focusing on these aspects, states can effectively foster confidence and contribute to a stable and secure international environment mediated by quantum technologies.

E: Routine "Evaluation" on the direction of the quantum investment

Regular exchanges and communication are critical to ensuring that quantum-related activities, projects, and the broader initiative remain aligned with the objective of nuclear risk reduction. This evaluation process should involve frequent meetings to assess progress and strategy, facilitate the exchange of reports to maintain transparency and track advancements, and engage external evaluators, such as UN working groups, to provide impartial assessments. Continuous communication among stakeholders is also essential for coordinating efforts and sharing updates. For the partners involved in quantum investment, it is important to hold regular meetings to review progress and adjust strategies as needed. Facilitating the exchange of reports will help maintain transparency and keep all parties informed about advancements and developments.

The primary aims of this evaluation and communication process are to build trust among parties through transparent and consistent communication, reassure all stakeholders of the commitment to stability, and ensure that quantum initiatives are effectively directed towards nuclear risk reduction while preventing any potential escalatory use of the technology. By focusing on these goals, states can strengthen collaborative efforts, maintain alignment with nuclear risk reduction objectives, and support the responsible development and application of quantum technology.

N: "Navigate" the framework in the long run

The navigation phase is dedicated to steering the initiative to ensure its long-term effectiveness and relevance, while strictly adhering to the rule of law and international governance standards. This phase entails developing a comprehensive long-term strategy designed to sustain the initiative over time. It is also advisable for states to position the initiative as a model for upholding legal and governance norms, incorporating values and principles that will guide its implementation and impact.

By establishing and promoting norms that discourage quantum-driven nuclear use, aligning all activities with the goals of nuclear risk reduction, and reinforcing commitments to the rule of law throughout its development and execution, the initiative will contribute significantly to strategic stability. States should craft a detailed long-term plan that ensures the initiative remains effective and sustainable, while also serving as a reference for upholding legal and governance standards.

The focus on these elements will help foster trust among stakeholders through transparent and consistent communication, reassure them of the commitment to stability and the responsible use

of quantum technology, and ensure that military quantum-related activities and projects are aligned with the goals of nuclear risk reduction while preventing potential misuse or use leading to nuclear escalation involving subsurface platforms. This approach will secure the longevity of the quantum initiative, reflecting the technology's enduring role and impact.

Conclusion

As quantum technologies advance, their dual-use nature, encompassing both civilian and military applications, poses significant challenges and opportunities for global security, especially within the undersea domain where nuclear deterrence and stability are critically intertwined. This paper underscores the need for a well-defined strategy to navigate the integration of quantum technologies into nuclear risk reduction efforts. The proposed SIREN framework provides a structured approach to managing these technologies, emphasising strategic collaboration, transparency, and continuous evaluation to align technological advancements with the goal of enhancing global security. By fostering international dialogue and adherence to peaceful applications, states can mitigate the risks associated with quantum advancements and contribute to a more stable and secure international landscape. The success of this framework relies on sustained commitment and cooperation among nations, aiming to prevent potential misuse and reinforce strategic stability in an era of rapid technological change.