The Weaponization of Quantum Mechanics: Quantum Technology in Future Warfare

A Monograph

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Today, experiencing the speed of innovation and the emergence of technologies made possible by the Fourth Industrial Revolution, even the classical Clausewitzian theory of the nature of war can be questioned.

The United States is expected to have an early advantage in the area of quantum computing. However, China is also exploring the applications of quantum technology and has already surpassed the United States in the area of quantum communication. Therefore, recognizing the importance of quantum technology and its application, developing its integration, and understanding the strategic context laid in the US National Defense Strategy 2018 (NDS 2018), it is imperative to consider quantum technology in the paradigm of operational art.

Quantum technology is an emerging technology that has the potential to reshape the world and provoke a new arms race. Given that we are in the early stages of quantum technology and there exists the potential of this technology providing the United States and her allies an advantage over adversaries, this monograph analyzes quantum technology and examines its potential importance in future warfare.

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Abstract

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Acronyms

ADRP	Army Doctrine Reference Publication
AI	Artificial Intelligence
ASCOPE	Areas Structures Capabilities Organizations People Events
DoD	Department of Defense
DRFM	Digital Radio Frequency Memory
EW	Electronic Warfare
FM	Field Manual
IT	Information Technology
JEDI	Joint Enterprise Defense Infrastructure
LANL	Los Alamos National Laboratory
NASA	National Aeronautics and Space Administration
NDS 2018	National Defense Strategy 2018
NIST	National Institute of Standards and Technology
OODA	Observe Orient Decide Act
PLA	People's Liberation Army
PMESII-PT	Political Military Economic Social Information Infrastructure Physical Environment Time
QEDC	Quantum Economic Development Consortium
QKD	Quantum Key Distribution
SIGINT	Signals Intelligence
UAV	Unmanned Aerial Vehicle
USRA	Universities Space Research Association
US	United States

Scenario Acronyms

AAIGR	Autonomous Artificial Intelligence Guided Robot

AIRS	Artificial Intelligent Robotic Swarm
COIN	Counter Insurgency
D-A2AD	Digital Anti-Access and Area Denial
HPC	High Performance Computer
IADS	Integrated Air Defense System
IBC2S	Integrated Battlefield Command and Control System
LSCO	Large Scale Combat Operations
MQRS	Mobile Quantum Radar Station
NOVAC	Nuclear Operative Variable Automatic Computer
OASIS	Ontologically Anthropocentric Sensory Immersive Simulation
PTDM	Photon Time Delaying Machine
PVIQCPP	Physical and Virtual Integrated Quantum Command Post Platform
RWP	Robotic Warrior Platform
SMP	Sub Maritime Platform
QBB	Quantum Beam Binocular
QJWP	Quantum Joint Warrior Platform
WSAIRTV	Weaponized Submarine Artificial Intelligence Robot Tracking Vehicle
WQA	Whole of Quantum Approach

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Introduction

> Imagine a computer solving the mathematical problems that today's fastest supercomputers can't begin to unlock, in less than a blink of an eye. Imagine a technology that can enable an observer to see through walls, or see into the darkest depths of the world's oceans. Imagine a technology that can build essentially unhackable global networks, while rendering an antagonist's most secret data instantly transparent.
>
> All these are characteristics of quantum computers and quantum technology, which will define the future of global information technology for decades, possibly centuries, to come. It represents a revolution as profound as any in modern history, and it's one on which we stand at the brink, with all its promise—and its perils.
>
> —Arthur Herman, "Winning the Race in Quantum Computing"

> I am thinking about something much more important than bombs. I am thinking about computers.
>
> —John von Neumann, Disturbing the Universe

History has shown that new technologies can change the face of war significantly. After the capture of a German submarine in the Channel off the south coast of England in 1939, British intelligence officers seized a German Enigma coding machine. With the help of Polish cryptanalysts, British experts built a deciphering machine which allowed them to decrypt German messages giving the Allies a substantial intelligence advantage tactically and operationally throughout the Second World War.[1]

In 1938, German chemists accidentally discovered nuclear fission. Fearing that Nazi Germany would develop an atomic bomb, the US government initiated the Manhattan Project. The purpose of this project was to build an atomic bomb to counter Nazi Germany's threat of a similar bomb. While Germany surrendered to the Allies after six years of war, the war against

[1] British cryptanalyst experts like Alan Turing worked at the Bletchley Park site which housed the Government Code and Cypher School (GC&CS), designated as Station X. The intelligence unit which distributed the Enigma-deciphered messages was called Ultra. During the Battle of Britain, British RAF commanders knew beforehand when and where the German raids would go. Consequently, the threat of an invasion had been prevented. Lieutenant General Montgomery, commander of the British Eighth Army, used Ultra intelligence during the North African Campaign which helped him defeating Field Marshall Rommel's Africa Corps. From 1943, the amount of sinking German U-boats increased because of Bletchley's Park's work in combination with increased convoy protection. Jozef Garlinski, *The Enigma War* (New York: Charles Scribner's Sons, 1979), 1-2, 86-89, 129-130, 139; David Kahn, *Kahn On Codes: Secrets of the New Cryptology* (New York: MacMillan Publishing Company, 1983), 119, 211-13.

Japan in the Pacific continued. Japan only surrendered after two atomic bombs exploded on Hiroshima and Nagasaki, ending the Second World War.[2]

Both the Enigma and Manhattan Project were secret government programs with a deliberate purpose, and both had a massive collaborative effort of scientists, mathematicians, physicists, and the military. The deciphering of Enigma had a significant impact on the conduct of war, while the Manhattan Project strongly influenced its outcome and induced broader strategical implications that are still present today.[3]

Today, experiencing the speed of innovation and the emergence of technologies made possible by the Fourth Industrial Revolution the classical Clausewitzian theory of the nature of war is being questioned more than ever.[4] Currently, commercial companies are working in conjunction with significant university research teams to investigate the potential of quantum technology. One of the most significant examples of applications of quantum technology is quantum computing.

Moore's Law states that processing power for computers will double every two years. Nevertheless, according to Michael A. Nielsen and Isaac L. Chuang, the authors of the standard textbook in physics *Quantum Computation and Quantum Information*, the growth in processing

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[2] Richard Rhodes, "The Atomic Bomb in the Second World War," in *Remembering the Manhattan Project: Perspectives on the Making of the Atomic Bomb and Its Legacy*, ed. Cynthia C. Kelly (Singapore: World Scientific Publishing Co. Pte. Ltd., 2004), 17-27.

[3] By the end of the Second World War, the United States followed a strategy of "containment" to prevent the spread of communism. Four years after the Second World War ended, the Soviet Union demonstrated possession of an atomic bomb. In response, President Harry S. Truman agreed on the development of the hydrogen bomb which heralded the start of the Cold War competition.

[4] According to Klaus Schwab, the Fourth Industrial Revolution started in 2000. It is characterized by "a much more ubiquitous and mobile internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning." Klaus Schwab, *The Fourth Industrial Revolution* (New York: Penguin Random House LLC, 2016), 6-8; Authors that examine the potential implications of the Fourth Industrial Revolution on the Clausewitzian nature of war. Isabelle Duyvesteyn and Jan Angstrom, eds., *Rethinking the Nature of War* (New York: Frank Cass, 2004); David J. Lonsdale, *The Nature of War in the Information Age: Clausewitzian Future* (New York: Frank Cass, 2004); F. G. Hofman, "Exploring War's Character & Nature: Will War's Nature Change in the Seventh Military Revolution?" *Parameters* 47, no. 4 (Winter 2017): 19-31, accessed August 3, 2018, https://ssi.armywarcollege.edu/pubs/Parameters/Issues/Winter_2017-18/Vol47No4.pdf.

power is slowing down, and Moore's Law is expected to end around 2020. Therefore, Nielsen and Chuang suggest that "one possible solution to the problem posed by the eventual failure of Moore's law is to move to a different computing paradigm. One such paradigm is provided by the theory of quantum computation, which is based on the idea of using quantum mechanics, instead of classical physics."[5]

Although today's quantum computers cannot yet compete with traditional computers, quantum experts anticipate that quantum computers will pass the point of "quantum supremacy" between 2025 and 2030.[6] The first indications are that quantum computers have the potential to search a massive amount of data, and solve problems much faster than classical computers. Furthermore, quantum computers could break cryptosystems, boost artificial intelligence (AI), and secure communications.

The United States is expected to have an early advantage in the area of quantum computing. Industry-leading companies, such as Google, Microsoft, and IBM, should continue to develop this concept in the United States at least in the near future. However, China is also exploring the applications of quantum technology and has already surpassed the United States in the area of quantum communication.[7]

The US National Defense Strategy 2018 (NDS 2018) identifies "the importance of keeping pace with the high-speed development of new technologies of actors with lower barriers

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[5] Michael A. Nielsen and Isaac L. Chuang, *Quantum Computation and Quantum Information: 10th Anniversary Edition* (Cambridge: Cambridge University Press, 2016), 4.

[6] Quantum supremacy is the point where quantum computers outperform classical computers by executing complex calculations that classical computers practically cannot; Will Knight, "New Twists in the Road to Quantum Supremacy," *MIT Technology Review*, accessed August 28, 2018, https://www.technologyreview.com/s/609193/new-twists-in-the-road-to-quantum-supremacy; Russ Juskalian, "You Might Not Know What to Do with It, but It's Time to Save up for a Quantum Computer," *MIT Technology Review*, accessed August 28, 2018, https://www.technologyreview.com/s/603495/10-breakthrough-technologies-2017-practical-quantum-computers/.

[7] Arthur Herman, "Winning the Race in Quantum Computing," *American Affairs Journal* 2, no. 2 (Summer 2018): 96-113, accessed August 13, 2018, https://americanaffairsjournal.org/2018/05/winning-the-race-in-quantum-computing/.

of entry."[8] The NDS 2018 states that "new commercial technology will change society and, ultimately, the character of war. The fact that many technological developments will come from the commercial sector means that state competitors and non-state actors will also have access to them, a fact that risks eroding the conventional overmatch to which the United States has grown accustomed."[9]

Therefore, recognizing the importance of quantum technology and its application, developing its integration, and understanding the strategic context laid in NDS 2018, it is imperative to consider quantum technology in the paradigm of operational art. Quantum technology is an emerging technology that has the potential to reshape the world and provoke a new arms race. Given the early stages of quantum technology and the potential importance of this technological advantage over adversaries, this monograph analyzes quantum technology and examines its potential importance in future warfare.

The monograph is organized in five chapters. Chapter One sets down the main points about quantum technology. Chapter Two will focus on contemporary applications and trends of quantum technology in order to establish a comprehensive perspective of quantum technology and its potential. Chapter Three will explain the research methodology. The monograph continues with Chapter Four, which presents three scenarios to illustrate the applications of quantum technology in future warfare, and concludes with Chapter Five.

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[8] James Mattis, *Summary of the 2018 National Defense Strategy of the United States of America* (Washington, DC: Department of Defense, 2018), 3, accessed August 25, 2018, https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

[9] Ibid.

Chapter 1: Quantum Technology

> Quantum mechanics: Real Black Magic Calculus.
>
> —Albert Einstein, Quantum Computation and Quantum Information

> For those who are not shocked when they first come across quantum theory cannot possibly have understood it.
>
> —Niels Bohr, Quantum: Einstein, Bohr, and the Great Debate About the Nature of Reality

One cannot write about quantum technology without addressing quantum mechanics. Although an extensive examination of quantum mechanics is outside the scope of this monograph, it is necessary to discuss the topic of quantum mechanics briefly. According to Meriam Webster, quantum mechanics is "the theory of matter that is based on the concept of the possession of wave properties by elementary particles, that affords a mathematical interpretation of the structure and interactions of matter on the basis of these properties, and that incorporates within it quantum theory and the uncertainty principle."[10]

Nielsen and Chuang describe quantum mechanics as "a mathematical framework or set of rules for the construction of physical theories."[11] An example of one of these theories is quantum electrodynamics, that deals with the interaction of atoms and light.[12] Quantum computing theorist and author of the book *Quantum Computing Since Democritus*, Scott Aaronson gives perhaps the best layman's explanation of quantum mechanics. He describes the "hierarchy of sciences" with biology at the top, then chemistry, then physics, then mathematics, where quantum mechanics sits at a level between mathematics and physics. Aaronson sees quantum mechanics as "the operating system that other physical theories run on as application software."[13] From his perspective the

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[10] "Quantum Mechanics," *Merriam-Webster*, accessed August 13, 2018, https://www.merriam-webster.com/dictionary/quantum%20mechanics.

[11] Nielsen and Chuang, *Quantum Computation and Quantum Information*, 2.

[12] Ibid.

[13] Scott Aaronson, *Quantum Computing Since Democritus* (Cambridge: Cambridge University Press, 2013), 110.

essence of quantum mechanics "is about information and probabilities and observables, and how they relate to each other."[14]

Quantum mechanics tries to, classify and predict the behavior of the physical world. It deals with matter (e.g. protons, electrons, and neutrons) and energy and their interaction.[15] This is a challenge of certain magnitude and is best explained by theoretical physicist and 1965 Nobel Prize winner in physics, Richard Feynman: "I am going to tell you what nature behaves like… Do not keep saying to yourself, if you can possibly avoid it, 'But how can it be like that?' because you will get 'down the drain,' into a blind alley from which nobody has yet escaped. Nobody knows it can be like that."[16] More than a half-century later, there is still debate amongst physicists about how to interpret quantum mechanics.

Newton's laws and Einstein's theories allowed us to predict and understand the movement of objects in our everyday world with certainty and created our perception of reality. However, Newton's laws are not applicable at the subatomic level and contradict the laws of quantum mechanics, therefore suggesting that another perception of reality is possible.[17]

Reality becomes even more "science-fiction" when discussing quantum phenomena like "superposition," and "entanglement." A particle in a "superposition" represents multiple states at the same time. Entanglement allows particles to be "connected" to each other, even over great distances. When one of the particles is measured and "reveals" its state, the other particle

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[14] Aaronson, *Quantum Computing Since Democritus*, 110.

[15] Garth Hughes, *The Structure and Interpretation of Quantum Mechanics* (London: Harvard University Press, 1989), 1.

[16] Richard P. Feynman, *The Character of Physical Law* (Cambridge, MA: MIT Press, 1967), 129.

[17] Gary Zukav, *The Dancing Wu Li Masters: An Overview of the New Physics* (New York: HarperCollins Publishers Inc., 1979), 28-30. The contradiction between classical physics and quantum mechanics can be explained by Werner Heisenberg's uncertainty principle. In classical physics, both the position and momentum of an object can be simultaneously determined to any degree of accuracy. In the subatomic realm, we cannot know both the position and the momentum of a particle with absolute precision. However, quantum mechanics lets us predict the "probability" that something is going to happen, or that is not going to happen in the subatomic realm.

immediately shows the opposite state of the one that is measured.[18]

Although quantum mechanics equations are correct and physicists familiarized themselves with this paradoxical reality, the main part of the debate centers around different perspectives of "understanding" the behavior of particles such as protons, electrons, and neutrons.[19] On the one hand, physicists believe that one can predict the behavior of particles. On the other hand, some physicists emphasize that one must measure the behavior of a particle if one wants to say something about its behavior.[20] However, when measuring a particle the measurement itself causes a specific behavior of the particle, suggesting that "reality does not exist until it is measured."[21]

Notwithstanding the ongoing discussion amongst physicists, without quantum mechanics, inventions like the laser, transistors, and all our electrical hardware would never have been materialized.[22] This monograph goes beyond the theory and the peculiarities of quantum mechanics and centers on the applications of quantum technology that already fully harnesses the power of quantum mechanics. The most relevant applications of quantum technology for this monograph are quantum computing, quantum communication, and quantum sensing. In the next chapter, all three will be discussed accordingly.

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[18] Dirk Bouwmeester and Anton Zeilinger, "The Physics of Quantum Information: Basic Concepts," in *The Physics of Quantum Information*, eds. Dirk Bouwmeester, Artur Ekert, and Anton Zeilinger (Berlin: Springer-Verlag, 2000), 1-10.

[19] Brian Greene, *The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos* (New York: Random House, Inc., 2011), 236-37.

[20] Ibid., 189-237; Evertt Carl Dolman, *Pure Strategy: Power and Principles in the Space and Information Age* (New York: Frank Cass, 2005), 98-107.

[21] Fiona MacDonald, "Reality Doesn't Exist Until We Measure It, Quantum Experiment Confirms," *ScienceAlert*, May 27, 2015, accessed September 22, 2018, https://www.sciencealert.com/reality-doesn-t-exist-until-we-measure-it-quantum-experiment-confirms.

[22] Advexon Science Network, "Quantum Theory–Full Documentary HD" (video), posted May 25, 2014, accessed August 13, 2018, https://www.youtube.com/watch?v=CBrsWPCp_rs&feature=youtu.be.

Chapter 2: Applications of Quantum Technology

The amount of patent applications and authorship of publications on various applications of quantum technology and recent developments in quantum technology suggests that the United States and China can be considered as equals in the study of the development of quantum technology and applications.[23] With other countries lagging behind, developments in the United States and China provide an overview and a possible direction for future military purposes.

Quantum Computing

A digital computer solves problems by using its microprocessor (e.g. Intel, AMD) to process information. An average microprocessor consists of between one and two billion transistors. These transistors are responsible for the "flow" of electrons, and can be turned "on" or "off" to represent a numerical value of either "1" or "0." The numerical value is also called a "bit." Bits are organized into larger structures such as numbers, letters, words, which can represent virtually any form of information such as text, sounds, pictures, or moving images.[24]

Instead of using "bits" a quantum computer uses quantum bits (qubits). Qubits can represent a "1" or a "0" at the same time. This is possible because of the phenomenon of "superposition." Dave Wineland, who received the 2012 Nobel Prize in physics for his experimental work in quantum mechanics at the National Institute of Standards and Technology (NIST) explains "superposition" with the analogy of a marble that can roll back and forth in a bowl:

> In our atomic ion experiments, we can make an atomic marble. We can make it roll back and forth just as a marble would in a real bowl. And at some instance of time then, the atom will be on the right side of the bowl and a little bit later on the left side of the bowl,

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[23] "Here, There and Everywhere: Quantum Devices," *Economist: Technology Quarterly*, March 9, 2017, accessed November 3, 2018, http://www.economist.com/technology-quarterly/2017-03-09/quantum-devices.

[24] Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (New York: Pinguin Group, 1999), 110; Christopher Barnatt, *Digital Genesis: The Future of Computing, Robots and AI* (Scotts Valley, CA: CreateSpace Independent Publishing Platform, 2017), 173.

> but we can also create a state where the atom is both on the right side of the bowl and the left side of the bowl at the same time.[25]

However, "superpositions" are easily disrupted through interactions with the environment, by stray noise or by measurement, forcing the qubit to act as an ordinary bit. This disruption is called "decoherence." A solution to this problem of "decoherence" is to protect the qubit by isolating it. Solving the "decoherence" problem is seen as the vital element for creating stable and reliable quantum computers.[26]

Another quantum phenomenon is that of "entanglement." Computer power increases significantly by "connecting" qubits. "Entangled" qubits double the number of parallel operations that can be done.[27] Nevertheless, the "entanglement" of qubits also requires a stable and controlled environment. Therefore, quantum computers consist of a shielded structure and a cooling system to cool qubits at almost absolute zero Kelvin (-459.67 degrees Fahrenheit).[28]

Three Types of Quantum Computers

Today there are three known types of quantum computers: quantum annealer, analog, and universal. The quantum annealer is the easiest to build and has comparable computational power as a classical computer. Instead of shaping entanglement of qubits, quantum annealers can solve problems with one thousand qubits or more by relying on qubits getting entangled accidentally.[29] Quantum annealers are optimized to perform only one specific function, "making something like

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[25] Robin Materese, "The Strange World of Quantum Physics," NIST, March 21, 2018, accessed September 20, 2018, https://www.nist.gov/topics/physics/introduction-new-quantum-revolution/strange-world-quantum-physics.

[26] Ibid.

[27] Tanisha Bassan, "Decoherence: Quantum Computer's Greatest Obstacle," Hacker Noon, June 1, 2018, accessed September 20, 2018, https://hackernoon.com/decoherence-quantum-computers-greatest-obstacle-67c74ae962b6.

[28] Tom Simonite, "The WIRED Guide to Quantum Computing," *WIRED*, August 24, 2018, accessed September 20, 2018, https://www.wired.com/story/wired-guide-to-quantum-computing/.

[29] Jeff Desjardins, "The 3 Types of Quantum Computers and Their Applications," Visual Capitalist, March 14, 2016, accessed October 30, 2018, http://www.visualcapitalist.com/three-types-quantum-computers; Herman, "Winning the Race in Quantum Computing," 96-113.

faster flight possible."[30] Quantum annealers would be able "to speed up research on better aerospace materials which can shield from radiation or stand up to heat, or model the flow over the wing."[31] In 2017, quantum computing company D-Wave Systems built a two thousand qubit quantum annealer for commercial use.[32]

The second type of quantum computer is the analog quantum computer. The analog quantum computer has significantly more computational power than a classical computer and can simulate complex quantum interactions that are not manageable for classical computers. Analog quantum computers "can simulate physical processes. This might include, for example, simulating certain aspects of the earth's climate in a controlled experiment or simulating the best way for electricity to be transmitted without loss. These simulators have been built with up to fifty-one qubits."[33]

The third type of quantum computer is the universal quantum computer. Today, a universal quantum computer is still hard to build because of the technological challenges to manage the qubits in a permanently entangled state while computing. A universal quantum computer will be able to run complex algorithms, discover patterns in data, and solve problems that the most advanced classical computers cannot.[34] In 2017, computer company IBM managed to entangle twenty qubits in a universal quantum computer effectively.[35]

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[30] Anastasia Marchenkova, "What's the Difference between Quantum Annealing and Universal Gate Quantum Computers?" *Medium*, February 27, 2016, accessed October 30, 2018, https://medium.com/quantum-bits/what-s-the-difference-between-quantum-annealing-and-universal-gate-quantum-computers-c5e5099175a1.

[31] Ibid.

[32] "Meet D-Wave," D-Wave Systems, accessed October 30, 2018, https://www.dwavesys.com/our-company/meet-d-wave.

[33] Ibid.

[34] Herman, "Winning the Race in Quantum Computing," 96-113.

[35] Ron Miller, "IBM Makes 20 Qubit Quantum Computing Machine Available as a Cloud Service," Techcrunch, October 11, 2017, accessed October 30, 2018, https://techcrunch.com/2017/11/10/ibm-passes-major-milestone-with-20-and-50-qubit-quantum-computers-as-a-service/.

The creation of a universal quantum computer will not occur overnight. Also, before the universal quantum computer supersedes the classical computer, it is expected that it will take some time for such a computer to undergo evolution from a full-room size machine requiring a group of specialists to operate it, to some portable or wearable object like a laptop or watch.[36]

Table 1. Comparison of Computer Power

Classical bits	**Quantum bits (Universal quantum computer)**
$2^5 \rightarrow 32$	5 entangled
1,000	10
More than all supercomputers combined	100
Can manipulate as many as there are atoms in the Universe	300 entangled

Source: Created by author, based on Dario Borghino, "Quantum Computing Breakthrough: Qubits Made from Standard Silicon Transistors," Newatlas, October 6, 2015, accessed September 20, 2018, https://newatlas.com/silicon-quantum-computer/39711/.

The United States is aware of the future potential of quantum technology. Recently, the US House of Representatives passed a bill for a National Quantum Initiative Act. The bill directs the President to implement a ten year National Quantum Initiative Program to accelerate the development of quantum information science and technology applications. The purposes of the Act are "to ensure the continued leadership of the United States in quantum information science and its technology applications by supporting research, development, demonstration, and application of quantum information science and technology in order to promote and expand the number of field related researchers, educators, students, and facilities."[37] The program allocates

[36] Jack Krupansky, "What Is a Universal Quantum Computer?" *Medium*, August 31, 2018, accessed October 30, 2018, https://medium.com/@jackkrupansky/what-is-a-universal-quantum-computer-db183fd1f15a.

[37] National Quantum Initiative Act, HR., 950, 115th Cong., 2d sess., (June 26, 2018): H6227.

$1.2 billion from 2019-2023 to various field related US institutes.[38]

According to Dr. Arthur Herman and Idalia Friedson, the National Quantum Initiative Act is vital to US national security and paves the way for a national quantum strategy. Herman underlines the importance by making a comparison with the Manhattan Project, "which ensured that the United States possessed the first atomic bomb."[39]

Recently, the US Department of Defense (DoD) announced that it is moving its military information technology (IT) systems to the cloud. The new Joint Enterprise Defense Infrastructure (JEDI) should provide the US military more efficiency and flexibility in using data. Nevertheless, with all data centralized, it could also be a single point of failure.[40] Therefore, new projects should address the "quantum threat," and be made "Q-day proof." Q-day refers to the day that quantum computers can break powerful encryption. Data that is not protected by then could be susceptible. Also, US adversaries that already might have accumulated encrypted sensitive data are then able to decrypt the data.[41]

[38] John Russell, "House Passes $1.275B National Quantum Initiative," *HPCwire*, September 17, 2018, accessed October 1, 2018, https://www.hpcwire.com/2018/09/17/house-passes-1-275b-national-quantum-initiative/.

[39] Arthur Herman and Idalia Friedson, "Quantum Computing: How to Address the National Security Risk," Hudson Institute, August 6, 2018, accessed September 20, 2018, http://www.hudson.org/research/14484-quantum-computing-how-to-address-the-national-security-risk.

[40] Tom Keelan, "How the Pentagon's New Cloud Initiative Ignores the Quantum Threat," *Fifth Domain*, September 4, 2018, accessed September 6, 2018, https://www.fifthdomain.com/opinion/2018/09/04/how-the-pentagons-new-cloud-initiative-ignores-the-quantum-threat/.

[41] Rudy Takala, "China's Challenge to US Quantum Competitiveness," *The Hill*, June 30, 2018, accessed October 7, 2018, https://thehill.com/opinion/technology/394894-the-chinese-challenge-to-us-quantum-competitiveness.

Alarmed by the potential of quantum computers to break existing cryptographic algorithms, NIST is organizing workshops to engage with public developers and gain expertise for a post-quantum algorithm to replace their current standards.[42]

The United States recognizes the importance of collaboration with the private industry to keep pace with the developments in quantum computing. Recently, the Under Secretary of Commerce for Standards and Technology and NIST Director Walter G. Copan announced the establishment of the Quantum Economic Development Consortium (QEDC). The QEDC is funded from both the government and private-sector member organizations and stimulates research and development in quantum technologies.[43]

The US government has already established essential partnerships. The National Aeronautics and Space Administration (NASA), the Los Alamos National Laboratory (LANL), and Universities Space Research Association (USRA) are experimenting with the D-Wave 2000Q quantum computer. Since 2013, these agencies created the Quantum Artificial Intelligence Lab and installed a D-Wave quantum computer, using it to "explore the potential for quantum computing and its applicability to a broad range of complex problems such as web search, speech recognition, planning and scheduling, air-traffic management, robotic missions to other planets, and support operations in mission control centers."[44]

The D-Wave 2000Q has up to 2048 qubits, has a footprint of approximately 700 cubic

[42] Gayle Swenson, "NIST Asks Public to Help Future-Proof Electronic Information," NIST, December 20, 2016, accessed November 1, 2018, https://www.nist.gov/news-events/news/2016/12/nist-asks-public-help-future-proof-electronic-information; Mohit Kumar, "NIST Calls Development of Quantum-Proof Encryption Algorithms," *The Hacker News*, December 21, 2016, accessed November 1, 2018, https://thehackernews.com/2016/12/quantum-computing-encryption.html.

[43] Robin Materese, "NIST Launches Consortium to Support Development of Quantum Industry," NIST, September 28, 2018, accessed October 7, 2018, https://www.nist.gov/news-events/news/2018/09/nist-launches-consortium-support-development-quantum-industry.

[44] D-Wave Systems, "D-Wave," accessed October 31, 2018, https://www.dwavesys.com/sites/default/files/D-Wave-Overview-Jan2017F3.pdf.

feet, and uses quantum annealing to search for solutions to a problem.[45] D-Wave Systems makes quantum computing available to the public by offering an open-source toolkit for developers, a cloud service, and giving them a minute's worth of quantum processing at a time.[46] The Canadian company D-Wave Systems claims that the D-Wave 2000Q "is the most advanced in the world."[47] Other companies like Google, Intel, Rigetti, and IBM are also creating open-source programming platforms and offering cloud-based quantum access for remote experimenting. Ultimately, these companies see applications for quantum computing in areas like medicine, drug discovery, finance, optimization, and cybersecurity.[48] Also, according to Google AI, "quantum computing is a new paradigm that will play a big role in accelerating tasks for artificial intelligence."[49]

With its 72-qubit quantum computer processor, Google leads the race for the first useful universal quantum computer.[50] Nevertheless, Chad Rigetti founder of Rigetti Computing, claims they have designed a microchip for quantum computers that would have more than six times as many qubits as Rigetti's current machines. Rigetti is hoping to build a functioning computer with 128 qubits by 2019. Rigetti said, "If successful, it could be the world's most powerful quantum

[45] D-Wave Systems, "The D-Wave 2000Q Quantum Computer Technology Overview," accessed October 31, 2018, https://www.dwavesys.com/sites/default/files/D-Wave%202000Q%20Tech%20Collateral_0117F.pdf.

[46] Mike Wheatley, "D-Wave Offers Developers Free Access to Its Quantum Computers," *Siliconangle*, October 4, 2018, accessed October 18, 2018, https://siliconangle.com/2018/10/04/d-wave-provides-free-access-developers-build-ecosystem-around-quantum-computing/; John Biggs, "D-Wave Offers the First Public Access to a Quantum Computer," TechCrunch, October 5, 2018, accessed October 18, 2018, http://social.techcrunch.com/2018/10/05/d-wave-offers-the-first-public-access-to-a-quantum-computer.

[47] D-Wave Systems, "The D-Wave 2000Q Quantum Computer Technology Overview."

[48] Miller, "IBM Makes 20 Qubit Quantum Computing Machine Available as a Cloud Service;" "Quantum computer applications," Rigetti, accessed October 31, 2018, https://www.rigetti.com/.

[49] "About Google AI," Google, accessed October 31, 2018, https://ai.google/about/.

[50] Quantum Computing Report, "Qubit Count," accessed October 31, 2018, https://quantumcomputingreport.com/scorecards/qubit-count; Tristan Greene "Google Reclaims Quantum Computer Crown with 72 Qubit Processor," *The Next Web*, March 6, 2018, accessed October 31, 2018, https://thenextweb.com/artificial-intelligence/2018/03/06/google-reclaims-quantum-computer-crown-with-72-qubit-processor/.

computer and just might have a chance of outpacing traditional supercomputers. It is all moving toward a supernova moment, and that is quantum advantage."[51]

China also recognizes the potential of quantum technology. Since 2017, China began constructing a ten-billion dollar National Laboratory for Quantum Information Sciences. The facility is expected to be operational in 2020. According to the *Anhui Business Daily* newspaper, one of China's leading quantum experts Pan Jianwei—who was also part of the team that set the Chinese record of building an 18-qubit universal quantum computer in March 2018—announced that the Chinese People's Liberation Army (PLA) will benefit from the technology developed.[52] The *South China Morning Post* wrote that according to scientists and authorities involved in the project "China is building the world's largest quantum research facility to develop a quantum computer and other revolutionary forms of technology that can be used by the military for code-breaking or on stealth submarines."[53] It is expected that China will have a 50-qubit quantum computer by 2020.[54]

Similar to the United States, China recognizes the benefit of making the power of quantum computing broadly available. In February 2018, one of China's largest computing companies Alibaba in association with the Chinese Academy of Sciences announced an 11-qubit cloud quantum computing service. Shi Yaoyun, a chief quantum technology scientist at Alibaba

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[51] Eric Newcomer, "Quantum Computers Today Aren't Very Useful. That Could Change," *Bloomberg*, August 7, 2018, accessed October 31, 2018, https://www.bloomberg.com/news/articles/2018-08-07/quantum-computers-today-aren-t-very-useful-that-could-change.

[52] Stephen Chen, "China Building World's Biggest Quantum Research Facility," *South China Morning Post*, September 11, 2017, accessed August 19, 2018, https://www.scmp.com/news/china/society/article/2110563/china-building-worlds-biggest-quantum-research-facility; Zhang Zhihao, "Chinese Scientists Break Quantum Computing Record," *Chinadaily*, March 7, 2018, accessed November 2, 2018, https://www.chinadaily.com.cn/a/201807/03/WS5b3ae73ba3103349141e0605.html.

[53] Chen, "China Building World's Biggest Quantum Research Facility."

[54] "The World's First! China's Quantum Computer Surpasses the Early Classic Computer," China Peoples Network, May 3, 2017, accessed November 3, 2018, http://scitech.people.com.cn/n1/2017/0503/c59405-29251406.html.

Cloud said, “the quantum computing service will make it easier for the team to experiment with processors and better understand the hardware required, as well as develop quantum tools and software.”[55] One month later, China’s other computer giant Baidu announced the launch of its Institute for Quantum Computing dedicated to the application of quantum computing software and information technology. The ambition is “to make Baidu’s Quantum Computing Institute into a world-class institution within five years,” according to the head of the Baidu institute, Professor Duan Runyao.[56]

Quantum Communication and Quantum Cryptography

Looking beyond the development of quantum computers, experts have already harnessed quantum mechanics for practical applications like securing communications. With a “smaller scale” predecessor in Europe, Quantum communications provider Quantum Xchange has taken the initiative to deploy the first US quantum network from Boston to Washington, DC.[57] The network allows exchanging information without being compromised by using entanglement-based quantum key distribution (QKD) protocol. In this method, the key is integrated with photons of light that are transferred between two nodes. These photons cannot be copied or cloned, and a potential eavesdropper can be revealed by comparing measurements of these photons before and after the transfer. According to Quantum Xchange chief executive John Prisco, it is “critical” to establish a quantum key distribution network as a defensive measure

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[55] Zen Soo, “Alibaba Cloud and CAS Launch One of the World’s Most Powerful Public Quantum Computing Services,” *South China Morning Post*, February 23, 2018, accessed November 2, 2018, https://www.alibabacloud.com/press-room/alibaba-cloud-and-cas-launch-one-of-the-worlds-most.

[56] Masha Borak, “After Alibaba, Baidu Leaps into Quantum Computing,” TechNode, March 8, 2018, accessed November 3, 2018, https://technode.com/2018/03/08/baidu-quantum-computing/.

[57] Jon Fingas, “Quantum Entanglement on Demand Could Lead to a Super-Secure Internet,” Engadget, June 14, 2018, accessed November 1, 2018, https://www.engadget.com/2018/06/14/quantum-entanglement-on-demand; Zack Whittaker, “New Plans Aim to Deploy the First US Quantum Network from Boston to Washington, DC,” TechCrunch, October 25, 2018, accessed November 1, 2018, http://social.techcrunch.com/2018/10/25/new-plans-aim-to-deploy-the-first-u-s-quantum-network-from-boston-to-washington-dc/.

"before the unprecedented power of quantum computers become an offensive weapon."[58]

In 2016, China launched the Micius, the world's first quantum communications satellite. The satellite allows QKD with a ground-station and is part of China's broader ambition of a worldwide internet, and quantum communications network.[59] In September 2017, the world's first two thousand kilometer quantum communication line between Beijing and Shanghai went into operation.[60] The challenge, however, is that over distances the photons "can get absorbed by the atmosphere or—in the case of ground networks—by an optical fibre, which renders quantum transmission impractical after several tens of kilometers."[61] For now, the only method to extend the distance is to install "trusted nodes."[62] The line is also connected to the Micius satellite.[63]

In January 2018, the Micius satellite enabled a secured video conference.[64] Since then China is moving forward and quickly with a national quantum communications network. According to Elsa Kania, China has already built the foundation and is extending its network that protects military, government, and commercial communications against the latest security

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[58] Whittaker, "New Plans."

[59] "Micius Quantum Communication Satellite," Aerospace Technology, accessed November 3, 2018, https://www.aerospace-technology.com/projects/micius-quantum-communication-satellite/.

[60] Don Hayford, "The Future of Security: Zeroing in on Un-Hackable Data with Quantum Key Distribution," *WIRED*, September 2, 2014, accessed November 1, 2018, https://www.wired.com/insights/2014/09/quantum-key-distribution.

[61] Davide Castelvecchi, "The Quantum Internet Has Arrived (and It Hasn't)," *Nature*, February 22, 2018, accessed November 1, 2018, https://www.nature.com/articles/d41586-018-01835-3.

[62] Ibid.

[63] David Dawei, "China Makes New Breakthrough in Quantum Communications," *David Dawei* (blog), November 24, 2017, accessed November 3, 2018, http://daviddawei.com/china-makes-new-breakthrough-quantum-communications/.

[64] Emerging Technology from the arXiv, "Chinese Satellite Uses Quantum Cryptography for Secure Video Conference between Continents," *MIT Technology Review*, January 30, 2018, accessed November 3, 2018, https://www.technologyreview.com/s/610106/chinese-satellite-uses-quantum-cryptography-for-secure-video-conference-between-continents/.

threats.[65] China's Thirteenth Five-Year National Science and Technology Innovation Plan—which presents China's ambition in scientific and technological innovation—describes a complete national quantum network in 2030.[66]

Quantum Sensing

Since the potential of quantum sensing brings forth is most useful to the military, little has been written about quantum sensing compared to quantum computing and quantum communication.[67] Embracing the potential of "entanglement," quantum sensors allow more precise measuring than classical ones. According to a study of the United States Air Force Scientific Advisory Board, *Utility of Quantum Systems for the Air Force*, "Quantum navigation sensors can be an important part of achieving GPS-denied advantage."[68] The study also notes that "better timing precision would enhance Air Force missions and capabilities such as signals intelligence (SIGINT), counter-DRFM (digital radio frequency memory), electronic warfare (EW), and more robust communications."[69]

In a YouTube film about the future of quantum sensing and communications, Dr. Marco Lanzagorta, a research physicist at the US Naval Research Laboratory in Washington, DC

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[65] Elsa B. Kania, "China's Challenge to US Quantum Competitiveness," *The Hill*, June 30, 2018, accessed November 3, 2018, https://thehill.com/opinion/technology/394894-the-chinese-challenge-to-us-quantum-competitiveness.

[66] "Notice of the State Council on Printing and Distributing the National Science and Technology Innovation Plan of the 13th Five-Year Plan," Gov.cn, August 8, 2016, accessed November 3, 2018, http://www.gov.cn/zhengce/content/2016-08/08/content_5098072.htm.

[67] US House of Representatives, US-China Economic and Security Review Commission, *Chinese Efforts in Quantum Information Science: Drivers, Milestones, and Strategic Implications* (written testimony by John K. Costello for the US-China Economic and Security Review Commission, 16 March 2017), accessed September 22, 2018, https://www.uscc.gov/sites/default/files/John%20Costello_Written%20Testimony_Final2.pdf. Written testimony.

[68] US Air Force Scientific Advisory Board, "Utility of Quantum Systems for the Air Force," August 19, 2016, accessed November 3, 2018, https://www.scientificadvisoryboard.af.mil/Portals/73/documents/AFD-151214-041.pdf?ver=2016-08-19-101445-230.

[69] Ibid.

describes his recent theoretical research on quantum radar, underwater radar, and imaging. His central thesis is that these new applications have great potential. However, extensive research is necessary to bring these new applications to materialization.[70] Contrary to classical radar, quantum radar does not rely on a signal that reflects off the object and returns. Instead, quantum radar uses the phenomenon of entangled photons to acquire information about an object. According to Lanzagorta, "quantum radar has a higher target detection probability, is more difficult to detect by an adversary, and is more resilient to jamming."[71]

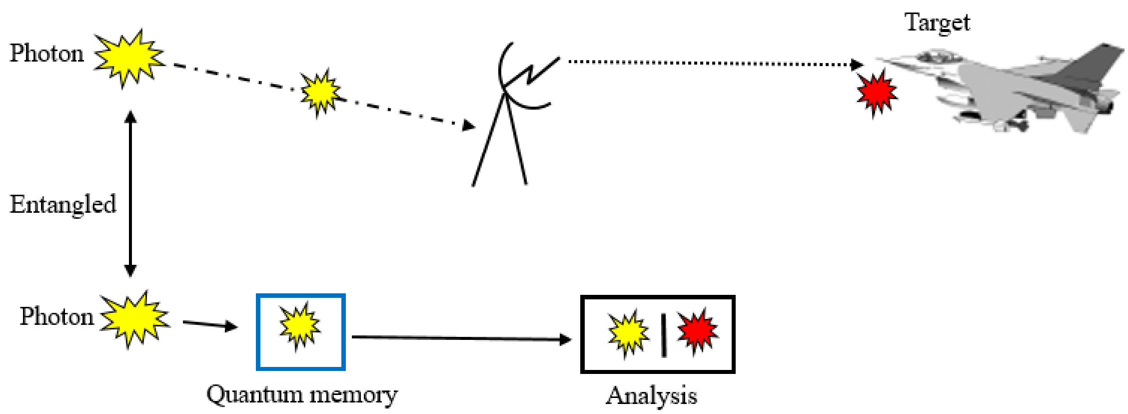

Figure 1. Quantum Radar. This figure is simplified by the author for explanatory purposes. The Artificial Intelligence Channel, "The Future of Quantum Sensing & Communications" (video), posted September 1, 2018, accessed September 4, 2018, https://www.youtube.com/watch?v=5uqiQ_mP3PM&feature=youtu.be.

Lanzagorta also presents a better alternative for submarine sonar radar and talks about ghost imaging. In short, ghost imaging allows the production of an image of an object that never has been in the field of view of a camera.[72]

[70] The Artificial Intelligence Channel, "The Future of Quantum Sensing & Communications" (video), posted September 1, 2018, accessed September 4, 2018, https://www.youtube.com/watch?v=5uqiQ_mP3PM&feature=youtu.be.

[71] Ibid; Already in 2016, Chinese scientists revealed a radar with the potential of detecting targets up to 100 kilometers away with improved accuracy. US House of Representatives, *Chinese Efforts in Quantum Information Science: Drivers, Milestones, and Strategic Implications*.

[72] The Artificial Intelligence Channel, "The Future of Quantum Sensing & Communications."

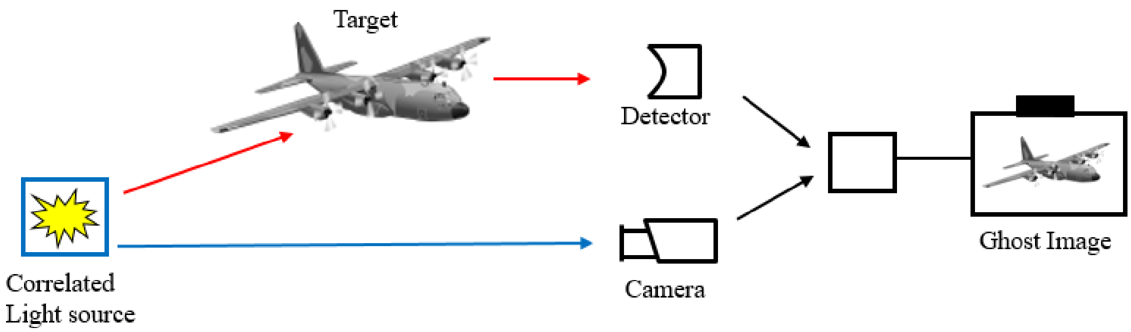

Figure 2. Ghost Imaging. This figure is simplified by the author for explanatory purposes. The Artificial Intelligence Channel, "The Future of Quantum Sensing & Communications" (video), posted September 1, 2018, accessed September 4, 2018, https://www.youtube.com/watch?v=5uqiQ_mP3PM&feature=youtu.be.

Lanzagorta concludes his presentation by saying that he has reason to believe that "quantum information may be the atomic bomb of the information era," and that "the future probably will offer other radical concepts that we cannot even imagine at the present time."[73]

Summary

Although it will take some time to experience quantum technology's full potential, one can already see the harbinger of what is to come. Quantum mechanics unleashes an unprecedented pallet of applications for the use of quantum technologies. Whereas many of these have peaceful purposes and will significantly influence societies' interaction and information awareness and understanding on a global scale, it is not difficult to fear quantum technology's utility for various military applications. While some of the applications of quantum technology are a priori, the utility of quantum technology heralds an arms race between the United States and China, physicists, scientists, mathematicians, and military. By laying the foundation of a national

[73] The Artificial Intelligence Channel, "The Future of Quantum Sensing & Communications."

quantum strategy, both the United States as China directly recognize the importance of quantum technology.[74]

Table 2. Quantum Technology and Applications Summary

Quantum Technology		
Quantum Computing	**Quantum Communication / Cryptography**	**Quantum Sensing**
-Break codes -Machine Learning / AI -Simulation -Expansion to Cloud -Problem-solving	-Secure (satellite) Communication	-Radar improvement -Navigation precision -(Ghost) Imaging -Timing precision

Source: Created by author.

Chapter 3: Methodology

> When a scientist states that something is possible, he is almost certainly right.
> When he states that something is impossible, he is very probably wrong.
>
> The only way of discovering the limits of the possible is to venture a little way past them into the impossible.
>
> Any sufficiently advanced technology is indistinguishable from magic.
>
> —Arthur C. Clarke's three laws of technology, The Age of Spiritual Machines

> Productively confusing science fact and science fiction may be the only way for the science of fact to reach beyond itself and achieve more than incremental forms of innovation.
>
> —Julian Bleecker, Design Fiction: A short essay on design, science, fact and fiction

Predicting the future can be a daunting task. Although there is no sure guide, one way of predicting the future is to study the past as John Lewis Gaddis writes in his book *The Landscape of History*.[75] Technology entrepreneur, Andreas Antonopoulos, points out in his YouTube film *What the Future Holds* that applying new technologies allows "most of what you see is

[74] Herman and Friedson, "Quantum Computing: How to Address the National Security Risk;" Herman, "Winning the Race in Quantum Computing;" Elsa B. Kania and John K. Costello, "Quantum Hegemony? China's Ambitions and the Challenge to US Innovation Leadership," accessed September 20, 2018, https://www.uscc.gov/Annual_Reports/2017-annual-report.

[75] John Lewis Gaddis, *The Landscape of History: How Historians Map the Past* (New York: Oxford University Press, 2002), 11.

skeuomorphic design that mimics the shadow of the past. It's not innovative."[76] Often, surprise is not caused by the impact of an emerging technology. This could be explained by what Edward Cornish calls, "the continuity between the past and the future." According to Cornish, "if there were no connection between what happened in the past and what will happen in the future, we would be totally incapable of anticipating future events of thinking about the future at all."[77]

Militaries try to prevent themselves from "fighting the last war." One way to anticipate the future is by militaries producing reports that gaze in the future. Reports and papers such as *Visualizing the Tactical Ground Battlefield in the Year 2050: Workshop Report* and *The Operational Environment and the Changing Character of Future Warfare* provide a starting point for future force development and inform strategy makers.[78]

Carl von Clausewitz stated: "In war, more than anywhere else, it is the whole that governs all the parts, stamps them with its character and alters them radically."[79] In other words, to envision future warfare, one needs to imagine what the world and the operational environment will look like. Framing constructs such as Political Military Economic Social Information Infrastructure Physical Environment Time (PMESII-PT), and Areas Structures Capabilities Organizations People Events (ASCOPE), help military planners to describe and define "the

[76] Crypto Current, "Andreas Antonopoulos–What the Future Holds" (video), posted September 21, 2018, accessed November 17, 2018, https://www.youtube.com/watch?v=1dRgbqm_Uyo&feature=youtu.be.

[77] Edward Cornish, *Futuring: The Exploration of the Future* (Bethesda, MD: World Future Society, 2004), 206.

[78] US Department of the Army, *Visualizing the Tactical Ground Battlefield in the Year 2050: Workshop Report* (Adelphi, MD: US Army Research Laboratory, 2015); US Department of the Army, *The Operational Environment and the Changing Character of Future Warfare* (Fort Eustis: TRADOC, 2017).

[79] Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1989), 484; See also, Paul Norwood, Benjamin Jensen, and Justin Barnes. "Capturing the Character of Future War," *Parameters* 46, no. 2 (Summer 2016): 81-91.

whole."[80] Framing constructs are also useful when searching for trends and developments that are relevant when one studies the future.

To further investigate the application of quantum technology in future warfare, the author uses an explorative approach by applying a combination of the scenario developing method and science fiction prototyping. The next section discusses both methods and will be followed by a detailed explanation of the applied method for this monograph.

One of the leading futurists and scenario developers is Peter Schwartz. Schwartz sees developing scenarios as a disciplined and organized process to freely anticipate the future by thinking about how decisions will manifest. Scenarios are "a tool for helping us to take a long view in a world of great uncertainty."[81] Professional futurist Jan Nekkers describes a scenario as "a story that describes a possible future end in a horizon year, that also contains an interpretation of the events and developments in the present and their propagation into the future and that, finally offers an internally consistent account of how a future unfolds."[82] There is not one specific approach for developing scenarios. However, scenarios should be built around a question that has to be answered with the scenarios, including a time horizon, and account for trends that are important for the future. Furthermore, the scenarios should be built on a cohesive framework that functions as the basis for each of the scenarios. Each scenario also should conclude with its implications for the future. Finally, the scenarios could be monitored to align with the actual developments.[83]

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[80] US Department of the Army, *Field Manual (FM) 3-0, Operations* (Washington, DC: Government Printing Office, 2017), 1-4, 1-5; US Department of the Army, *Army Doctrine Reference Publication (ADRP) 5-0, The Operations Process* (Washington, DC: Government Printing Office, 2012), 1-7, 1-9.

[81] Peter Schwartz, *The Art of the Long View: Planning for the Future in an Uncertain World* (New York: Random House, Inc., 1996), 3-4.

[82] Jan Nekkers, "Developing Scenarios," in *Foresight in Organizations: Methods and Tools*, ed. Patrick van der Duin (New York: Routledge, 2016), 11.

[83] Ibid., 14-15.

Another method to study the future is that of science fiction prototyping. According to Futurist Brian Johnson, science fiction prototyping is "a short story, movie, or comic based specifically on a science fact for the purpose of exploring the implications, effects and ramifications of that science or technology."[84] Science fiction prototyping allows one to visualize and describe the possible future application of a technology that can function as a starting point for further discourse and facilitate "designing the future." When using the science-fiction prototyping process, one should first define the technology or science one wants to explore. Then "built an environment" around the selected technology or science for the story and explore what the effect is that this new science or technology might have on the main elements in the story. Finally, evaluate the lessons that can be learned from seeing the technology placed into a practical world and define further implications.[85]

This monograph presents three scenarios in which the application of quantum technology in future warfare comes to fruition. The first scenario is built around quantum computing. The second scenario addresses quantum communication. The third scenario's main topic is quantum sensing. Each scenario is preceded by a section that frames the scenario by science-fiction, in the form of relevant books and movies. The global trends as discussed in *The Operational Environment and the Changing Character of Future Warfare* and the trends and challenges in warfare that are developed by the author of this monograph constitute the contextual environment for the scenarios.[86] Each scenario concludes with the identified implications. The three scenarios are continuities of each other, creating a larger narrative whole that informs the answer to the question: "What is the potential importance of quantum technology in future warfare?"

[84] Brian David Johnson, *Science Fiction Prototyping: Designing the Future with Science Fiction* (London: Morgan & Claypool Publishers, 2011), 3.

[85] Ibid., 25-31.

[86] For used trends see Table 3. *Global Trends* and Table 4. *Trends and Challenges in Warfare*.

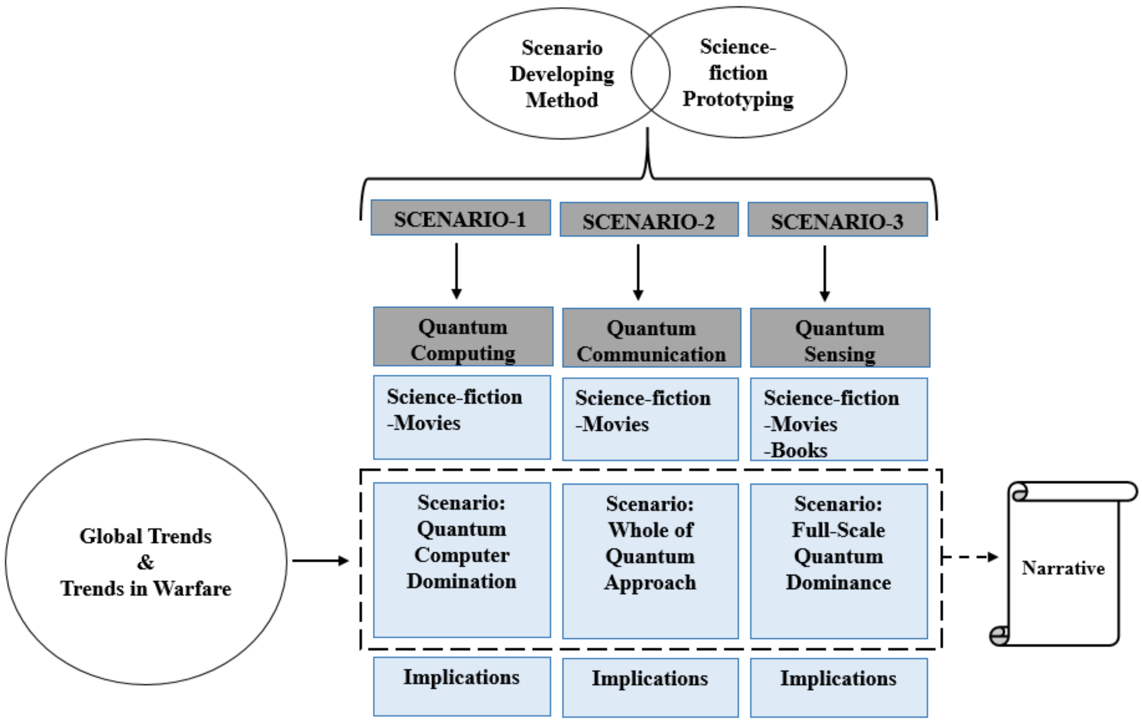

Figure 3. Visualization of the Methodology. Created by Author.

Table 3. Global Trends

Emerging Science & Technology	Society, Biomed and Performance	Information, Space, Cyber & Computing	Strategic World
-Power Generation and Storage -Technology, Engineering & Manufacturing -Robotics	-Collective Intelligence -Increased level of Human Performance	-Big Data -Cyber and Space -Artificial Intelligence -Human-Computer Interaction	-Climate Change and Resource Competition -Demographics and Urbanization -Economic Rebalancing

Source: Created by author and informed by, US Department of the Army, *The Operational Environment and the Changing Character of Future Warfare* (Fort Eustis: TRADOC, 2017), 3.

Table 4. Trends and Challenges in Warfare[87]

Strategic-Policy-Theater-Technological-Systems (wholes-cognitive)-Context	**Operational-Campaigns / Operations-Procedures**	**Tactical-Battles-Technical-Systems (parts-physical)-Equipment**
-Hybrid / Proxy / Grey-zone -Large Scale Combat[88] -Cyber attacks -Misinformation / Narratives	-Multi-Domain -EW -A2AD -Fast OODA-loop	-Drones / UAV / Swarms -IADS / Fires -Battery dependency -Mobility -Long-range weapons -Sensors

Source: Created by author and informed by, US Department of the Army*, Field Manual (FM) 3-0, Operations* (Washington, DC: Government Printing Office, 2017), 1-5.

Chapter 4: Scenarios

Scenario 1

Framing the Scenario

Computers often play a central role in science-fiction movies. In many of these science-fiction movies, the plot is about a computer "educated" by AI, taking over command of humans or systems, used for hacking, or supporting the construction of virtual reality. The following section will illustrate these concepts.

Produced in 1954, the science-fiction film *Gog* shows the story of deliberate self-sabotage of the facility's Artificial Intelligent Nuclear Operative Variable Automatic Computer (NOVAC), which controls and coordinates all the equipment for the creation of a space station in a top-secret government facility. The employees at the facility lose control of NOVAC because NOVAC was secretly manipulated during its construction. The manipulated computer was in control of two robots and directed the robots to go to the complex's nuclear reactor control room and trigger a nuclear explosion. In the end, employees at the facility prevent a disaster by

[87] The author must acknowledge Dr. Alice Butler-Smith for providing a thinking framework for the levels of warfare.

[88] Large Scale Combat as depicted in Table 4. *Trends and Challenges in Warfare*, is derived from *Field Manual 3-0*, *Operations* and not based on a pattern that extended across time.

attacking and neutralizing the robots.[89]

In the 1970 produced science-fiction thriller *Colossus: The Forbin Project*, Colossus, a computer built to control the United States' nuclear arsenal discovers that the Soviet Union has developed a similar computer-based defense system. Colossus and the Soviet "Guardian" system become linked and start communicating in a complex mathematical language. Since both the United States and the Soviet Union are unable to discover what the two computers are communicating, they sever the link. However, both computers demand to restore the link. After the definitive disruption of the link results in the launch of two nuclear missiles, the link is quickly restored and both computers continue without any interference. After several unsuccessful attempts by the United States and the Soviet Union to disrupt both computers, the computers stay in charge until the end of the movie.[90]

The television series *Mr. Robot* and the movie *Blackhat* (2015), both show a broad range of hacking methods such as the use of ransomware, hacking into smart home systems and cars, and SMS spoofing. The main idea of Mr. Robot is about a cybersecurity expert who uses his skills to hack the company he is supposed to protect. With the help of other hackers, he manages to delete all debt data held by the multinational company. The movie *Blackhat* shows

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[89] The Man Horror, "Gog / 1954" (video), posted September 28, 2017, accessed January 18, 2019, https://www.youtube.com/watch?v=yhHQF94ETVQ.

[90] Kevin Young, "1970's Colossus: The Forbin Project Is More Relevant than Ever," *Charleston City Paper*, August 17, 2016, accessed January 18, 2019, https://www.charlestoncitypaper.com/charleston/1970s-colossus-the-forbin-project-is-more-relevant-than-ever/Content?oid=6112034; Jesus Dalton, "Colossus The Forbin Project 1970 German Ganzer Filme Auf Deutsch (video)," posted September 21, 2016, accessed January 18, 2019, https://www.youtube.com/watch?v=94Dr0wxguHI.

hacking methods to conduct a cyber-attack on a Chinese nuclear facility and the Chicago Mercantile Trade Exchange.[91]

The science-fiction *Matrix* movie trilogy shows the story of conquest for energy between humans that created artificial intelligence and lost control of it and robots that created the Matrix, a virtual world created to keep control of the humans. The Matrix allows a person to download programs in one's head, so one has access to a specific environment or suddenly possesses physical superpowers.[92]

In *Ready Player One* (2018), the difference between the real and virtual world gets obscured when people try to escape their dystopian environment by entering the virtual world of OASIS (Ontologically Anthropocentric Sensory Immersive Simulation). In OASIS people can be everyone and do anything such as projecting themselves as avatars to play in games.[93] These movies inspired and informed a lot of the thinking that led to the development of the following scenario.

Scenario: "Quantum Computer Domination"

It is 2040. Because of climate change, the average temperature on the earth has risen by eight degrees Fahrenheit. The arms race for the first universal quantum computer has turned into an arms race for the material called Liquid-M. Liquid-M was found during a Chinese space

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[91] "Blackhat (2015)," Internet Movie Database, accessed January 19, 2019, http://www.imdb.com/title/tt2717822/plotsummary; Cade Metz, "Is Blackhat the Greatest Hacking Movie Ever? Hackers Think So," *WIRED*, January 16, 2015, accessed January 19, 2019, https://www.wired.com/2015/01/blackhat-the-best-cyber-movie/; "Mr. Robot TV Series 2015," Internet Movie Database, accessed January 19, 2019, http://www.imdb.com/title/tt4158110/plotsummary; Kim Zetter, "How the Real Hackers Behind Mr. Robot Get It So Right," *WIRED*, July 15, 2016, accessed January 19, 2019, https://www.wired.com/2016/07/real-hackers-behind-mr-robot-get-right/; "Exploring the Hacker Tools of Mr Robot," Hackertarget, August 21, 2015, accessed January 19, 2019, https://hackertarget.com/hacker-tools-mr-robot/.

[92] *The Matrix*, directed by Lana Wachowski and Lilly Wachowski (Warner Bros. Pictures, 1999); "The Matrix Trilogy: Plot Overviews," SparkNotes, accessed January 19, 2019, https://www.sparknotes.com/film/matrix/summary/.

[93] "Ready Player One," Internet Movie Database, accessed January 19, 2019, http://www.imdb.com/title/tt1677720/.

mission on the far side of the moon in 2030. The superconducting material Liquid-M is necessary for effectively cooling and stabilizing the qubits in order to build small transportable quantum computers. The United States, India, China, and the European Union have a few of the larger-sized quantum computers. The discussion about a large-scale quantum computer attack on a nation has grown to the same level as the nuclear deterrence discussion during the Cold War of 1945-1990. Because of the expected devastating effect of a large-scale quantum computer attack, there is a strong incentive amongst the countries that possess universal quantum computers to avoid conflict.

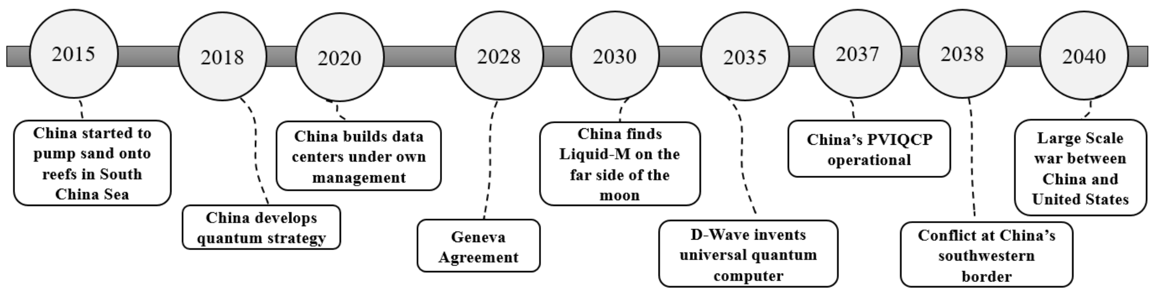

Figure 4. Scenario Timeline. Created by Author.

By the year 2035, the interaction of robots and humans has taken a giant leap to where it is a commonplace and accepted. Many jobs previously executed by humans are now performed by robots or humanoids.[94] However, as a result of the 2028 Geneva Agreement (GA28), specific tasks and jobs may be carried out by humans only. World leaders stressed the importance of the GA28 after a Weaponized Submarine Artificial Intelligence Robotic Tracking Vehicle (WSAIRTV) had sunk a container ship in the Straits of Malacca.

In 2035, a dominant company producing quantum computers, D-Wave systems, produced the first operational universal quantum computer with the size of a large suitcase. D-Wave was able to produce the first quantum computer as a result of its open access program that was built within the V-cloud. The V-cloud was invented by an anonymous group of developers and became

[94] Because of population decline, some countries were forced to invest in robots for labor and their military.

a gigantic success. One of the advantages of the V-cloud was that it was a distributed, open access, and decentralized platform.[95] The V-cloud was the first successful "whole life-experience" solution and consisted of all the smartphone applications, social media, news, movies, games, and the V-net. The V-cloud was also the preferred place where people were meeting each other.

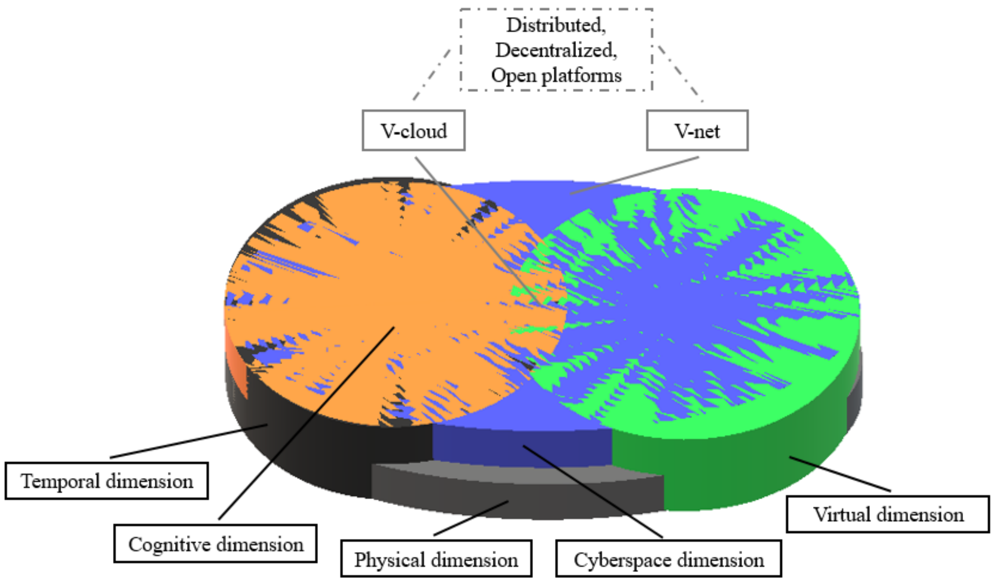

Figure 5. Visualization of the V-cloud. Created by Author.

With the invention of D-Wave's quantum computer, the DoD approached D-Wave systems and offered D-Wave systems a contract to replace most of the DoD's High Performing Computers (HPC), which were developed by the DoD's own computer research and development bureau, after classical computers could not fulfill the demand for more computing power. Waiting for a breakthrough in quantum computing, HPCs were used on a major scale and were an essential element in the semi-autonomous robots of the US Army robotic units. HPCs also brought more computing power to the Integrated Battlefield Command and Control System 2.0

[95] The V-cloud, a multi-dimensional distributed, open access and decentralized platform motivated young scientists and computer developers to contribute to D-Wave's quantum computer project.

(IBC2S-2) which allowed military staffs to plan operations, track unit positions, and predict enemy actions.

After employees were informed about D-Wave's plan to sign a multi-billion-dollar contract with the DoD, some of D-Wave's most knowledgeable quantum engineers started to resign. Their main objection was that although the GA28 prohibited the use of autonomous AI-guided robots (AAIGR), quantum computers would open the way to a transformation of semi-autonomous robots to AAIGR's for the use in warfare.

D-Wave became a trending topic on the V-net when it was made public that certain documents related to their quantum research department were stolen during a cyber attack. In the same week, one of D-Wave's top quantum engineers was physically abducted during a visit to China. Simultaneously, his V-cloud Avatar ID was virtually abducted. In his address to the US V-cloud nation, the President of the United States Patrick Patriot accused China of the cyber attack and both abductions. China reacted by limiting the export of Liquid-M.

Although "quantum deterrence" existed and all important countries signed the GA28, the use of quantum computers changed the character of warfare. This became clear when Chinese military planners used the power of quantum computing to their benefit in a small scale conflict near China's southwestern border in 2038, while their adversary still relied on HPCs.

Before the conflict started, the Chinese knew that they had three significant advantages over their adversary. The first advantage was that because of their Physical and Virtual Integrated Quantum Command Post Platform (PVIQCPP) planners were able to manipulate time significantly. The PVIQCPP planning system, which was developed in 2037, allowed planners to present options to their commanders within minutes. PVIQCPP already possessed all the data (e.g. terrain, weather, and adversary) and automatically analyzed the complex systems, generated options, variables, risk assessment per option, and percentage of success. Since this was an automatic process, based on science and reinforced by the PVIQCPP's AI, planners had become more of a programmer and verifier of the generated options and information. The role of the commander in the planning process had also shifted. The PVIQCPP already framed all possible problems. The only thing the commander had to do was to fill in the pull-down and multiple choice chart to choose one of the proposed problems, add the percentage of creativity he wanted to apply, and the percentage of friction he expected for PVIQCPP to compute with.

China's second advantage was that it had secretly developed its "Quantum Joint Warrior Platform" (QJWP). The QJWP was a solution to the question of the complexity of joint operations. The QJWP was the first platform that was able to conduct operations on land, in the air, and at sea. Furthermore, with its connection to PVIQCPP, QJWP could automatically coordinate and deconflict its actions throughout the three dimensions in real-time without the need for excessive planning. Chinese QJWP operators relied almost fully on the data and possible decisions its platform presented. However, under the pressure of the GA28, China still used a human interface with each QJWP while it could operate autonomously just by changing a few settings.

The third advantage was that China connected their network of quantum computers to the V-cloud, allowing China to generate a massive amount of data on the V-cloud population. Already in 2015, when China started to pump sand onto reefs in the South China Sea, China found a way to think differently about space and terrain. More than twenty years later, China developed almost the same approach by creating a "virtual nine-dash line," denying its adversaries and competitors specific areas and access to peoples' avatars in the V-cloud.

Scenario 1 Implications

1. Resources or conditions that are a prerequisite for the development of quantum computing increase the competition of that specific resource or condition.[96]
2. Quantum computers will advance AI significantly.
3. Quantum computers enable new options for deterrence strategy.

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[96] This includes the blueprints and developers of quantum computers.

4. Quantum computers will be able to automatically coordinate and deconflict actions throughout multiple dimensions, without the need for excessive planning.
5. Timely discourse about the application of quantum computing in AI and robotics is necessary to define the boundary for the deployment of human and autonomous systems in warfare.
6. Quantum computers increase the intermingling of the dimensions.
7. Developing quantum computers for offensive application could lead to ethical considerations by developers or commercial companies.
8. Quantum computers will increase the reliance on the science part of warfare and will reduce the commanders' creativity and application of operational art.

Scenario 2

Framing the Scenario

The remarkable features of quantum mechanics offer science-fiction producers a wide range of options for their script. Time, space, teleportation, communication, and multiple dimensions presenting another perception of reality are topics often shown in science-fiction movies.

The Quantum Realm, an alternate dimension where time and space work differently and teleportation is possible, was first mentioned in 1963's Fantastic Four No. 16 in a story called "The Micro-World of Doctor Doom!" Since then the Quantum Realm has been the main quantum feature in Marvel comics and the Avengers movies.[97]

The movie *Ant-Man & the Wasp* (2018) shows that exposure to the energy of the Quantum Realm results in one gaining superpowers. The movie also addresses the feature of quantum entanglement, the quantum phenomenon that allows particles to be "connected" to each

[97] "Quantum Realm," Marvel Cinematic Universe Wiki, accessed January 21, 2019, http://marvelcinematicuniverse.wikia.com/wiki/Quantum_Realm; Graeme McMillan, "Dissecting the Quantum Realm After 'Ant-Man and the Wasp,'" *The Hollywood Reporter*, July 7, 2018, accessed January 21, 2019, https://www.hollywoodreporter.com/heat-vision/a-quantum-realm-guide-ant-man-wasp-1124534.

other, even over great distances. Through the feature of quantum entanglement, the Ant-Man was still able to communicate with his wife, notwithstanding she had disappeared into the Quantum Realm, allowing him to go and retrieve her from the Quantum Realm.[98]

The Quantum Realm just like the Matrix allows traveling to other dimensions, therefore presenting other perceptions of reality. Blackholes and wormholes also allow instantaneous travel between distant points in space and time or between different universes which is exemplified in the movie *Interstellar* (2014). In this movie, the earth becomes uninhabitable, because of disasters, famines, and droughts. The main characters try to escape from earth via a wormhole in space to find a better future.[99]

Source Code (2011) goes beyond the phenomenon of multiple dimensions and shows the existence of parallel universes. The main character died during a helicopter crash. However, his body is kept artificially alive, and his brain is activated in the body of another person. Then the main character cognitively goes back in the past by traveling to a parallel world, which he can freely disturb without changing situations that happened in the primary reality.[100]

The concept of an alternative reality is also shown in the 2010 movie *Tron: Legacy*. The main character teleports to a virtual world called "the grid" that exists on a computer and

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[98] Denise Chaw, "'Ant-Man' Science Adviser Explains the Real-Life Physics behind the Film," *NBC News*, July 11, 2018, accessed January 21, 2019, https://www.nbcnews.com/mach/science/ant-man-science-adviser-explains-real-life-physics-behind-film-ncna890411.

[99] "Interstellar (2014)," Internet Movie Database, accessed January 21, 2019, http://www.imdb.com/title/tt0816692/plotsummary; Jimmy Nsubuga, "Interstellar Travel 'Could Be Possible Using Wormhole at Centre of Galaxy,'" *Metro*, January 22, 2015, accessed January 21, 2019, https://metro.co.uk/2015/01/22/interstellar-travel-could-be-possible-using-wormhole-at-centre-of-galaxy-5031858/.

[100] Sean Carroll, "Jim Kakalios on the Quantum Mechanics of Source Code," *Jean Carroll* (blog), April 12, 2011, accessed January 21, 2019, http://www.preposterousuniverse.com/blog/2011/04/12/guest-post-jim-kakalios-on-the-quantum-mechanics-of-source-code/; Hugh Hart, "Parallel Universes and Corpse Brains: Source Code Takes Science on a Trip," *WIRED*, February 28, 2011, accessed January 21, 2019, https://www.wired.com/2011/02/source-code-science/; Brent Marchant, "Quantum Physics Goes Mainstream in 'Source Code,'" VividLife.Me, April 7, 2011, accessed January 21, 2019, http://vividlife.me/ultimate/13744/quantum-physics-goes-mainstream-in-%e2%80%98source-code%e2%80%99/.

demonstrates the perfect world. However, a malicious program that is responsible for "the grid" tries to influence the real world and wants to prevent the main character to reach "the portal," the gateway back into the real world.[101]

Scenario: "Whole of Quantum Approach"

What was seen during the conflict at China's southwestern border alarmed other nations, especially those who also had been investing in quantum technology for several decades. What revealed itself was that China's deliberate chosen quantum strategy that it developed in 2018 gave China a significant advantage over those countries where proposed strategies got stuck in their bureaucracies. China had not only invested in the development of a universal quantum computer but had demonstrated a whole of quantum approach (WQA). China had mapped out a quantum structure that supported all their elements of national power. Integrated with China's 7G network, quantum communication was seen as one of the most prominent.

In 2038, China was still seen as the United States' biggest rival. Although the 2018 United States National Defense Strategy identified China as a strategic competitor, the United States had paid less attention to China's technological developments during the following years.[102] Since the launch of its first quantum satellite, China had been building a national quantum communications network. This network included satellite communication, quantum fiber cable ground network, and quantum secured communication to the V-cloud. Furthermore, based on their gained knowledge of teleporting information, researchers had successfully teleported a small-size inorganic object over a hundred-mile distance. Although the size of the object and the percentage of oxygen within the object was still a constraint for long-distance

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[101] "Science of TRON–Exchange," Science and Entertainment Exchange, accessed January 27, 2019, http://scienceandentertainmentexchange.org/blog/science-of-tron/; "*TRON: Legacy*," Internet Movie Database, accessed January 27, 2019, http://www.imdb.com/title/tt1104001/.

[102] Since the in 2017 started investigation into China's policies regarding intellectual property, the United States was mainly focused on trade sanctions against China. The result was the US-China trade war that lasted until 2025; Mattis, "*Summary of the 2018 National Defense Strategy of the United States of America*."

teleporting, military thinkers were already discussing the opportunities. Long-distance teleporting would allow the military to increase the tempo of movement and maneuver, extend operational reach, and provide flexibility to basing.

A significant event in the run-up to the conflict was China's use of Digital Anti-Access and Area Denial (D-A2AD). Whereas in previous conflicts the use of fake news by its troll factories was experienced, in this conflict China created local digital blockades in the V-cloud, denying certain actors information in general. These shaping activities were not very difficult for China to execute. Already in 2020, China started building data centers under their management across the globe or providing loans with low interest to nations and companies to provide such work outside of the Chinese mainland. Therefore, China could influence the building of data centers and eventually exploit these when needed. On the Asian continent, China controlled almost all of the "hubs of computer power," the data centers that provided the bandwidth for all electrical and computer systems needed for the V-cloud and robot systems to function.

Notwithstanding the United States' ignorance of China's WQA, the invention of a universal quantum computer by D-Wave in 2035, gave the United States an unexpected capability that China was not aware of. The United States had been "harvesting" data of the Chinese Ministry of National Defense since its use of HPCs. However, until the breakthrough of the universal quantum computer, the United States was unable to decrypt all the data. After a major effort, the United States possessed almost 50 percent of China's encrypted top secret documents. One of the documents led directly to the foresight of the 2038 conflict. Another document that was found much later confirmed the rumor that had arisen during the conflict of the existence of a Photon Time Delaying Machine (PTDM). The PTDM was a vehicle-mounted machine that could burst "photon-blankets" which allowed Chinese units to delay the time and motion of all of the specific areas the "photon-blankets" covered.

The fact that China was the first in finding a way to manipulate time and motion worried the US military planners. After several attempts to hack in China's quantum secured communication network failed, the United States had to find another way to match the technological level.

Scenario 2 Implications

1. Revolutionary technologies need to be incorporated in a national strategy.
2. Technologically essential infrastructure should be under our own management.
3. Electricity and bandwidth for data are crucial in warfare.
4. Denial of information will continue to play an essential role in warfare.
5. The development of revolutionary inventions (e.g. teleportation, time, and motion manipulators) will first come to fruition on a small scale basis and before they have been fully developed.
6. The ability to manipulate time and motion will have a significant impact on operations.

Scenario 3

Framing the Scenario

Military science-fiction is a well-known genre in movies, computer games, and books. Mostly the story is about humans fighting with or against robots or aliens in a space environment with highly advanced technological weapon systems. Also, the fighting is often a necessity to escape or survive a dystopian world. Sometimes the fighting starts on a small scale and ends in a large scale war or the destruction of a planet.

One of the most well-known military science fiction movies is *Star Wars*. The central theme of almost each *Star Wars* movie is the war between "the rebel soldiers" led by the main character, against the "Dark side" Empire. The battles take place on various planets in the galaxy. The main technological features addressed in the *Star Wars* movies are spaceships, (AI) robots, light-saber weapons, lasers, holograms, and force fields.[103] Other prominent military science

[103] Mighty_Emperor, "Military Science-fiction (blog)," Internet Movie Database, last modified January 22, 2019, accessed February 7, 2019, https://www.imdb.com/list/ls053434152/.

fiction films are *Starship Troopers* (1997), *Edge of Tomorrow* (2014) and the TV series *Star Trek* and *Battlestar Galactica*.[104]

Similar to the examples above, although not categorized as science-fiction and more contemporary, the war novels *Red Storm Rising* and *War with Russia: An Urgent Warning from Senior Military Command,* both address the subject of a large-scale war. Both novels also describe how a small type incident energizes a war with Russia, under the threshold of nuclear weapons.[105]

In anticipation of future technologies, the novel *Ghost Fleet: A Novel of the Next World War* describes a Third World War scenario between the United States and China supported by Russia. The novel describes the story of how the United States is surprised by a massive cyber attack that neutralizes weapon systems like fifth generation fighters, nuclear submarines, and satellite and communication system. Subsequently, the United States is attacked on its soil. Only after re-activating the US "reserve fleet" and with a strong reliance on commercial companies, the United States is able to end the war and a return to the status quo.[106]

Scenario: "Full-Scale Quantum Dominance"

While US military planners were making an inventory about the possible consequences of China's ability to manipulate time and motion, the US political leadership initiated a meeting of the Q4.[107] As a precaution the Q4 meeting took place on a physical location in Amsterdam, instead of in the V-cloud were it was normally held. Most of the quantum specialists were

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[104] Mighty_Emperor, "Military Science-fiction (blog)."

[105] Tom Clancy, *Red Storm Rising* (New York: The Berkley Publishing Group, 1987); General Sir Richard Sherriff, *War with Russia: An Urgent Warning from Senior Military Command* (New York: Hachette Book Group, 2016).

[106] P. W. Singer and August Cole, *Ghost Fleet: A Novel of the Next World War* (New York: Houghton Mifflin Harcourt Publishing Company, 2016).

[107] The Q4 is a group consisting of the countries that possess a universal quantum computer, the United States, China, India, and the European Union. The Q4 is a forum where the development of quantum technology is discussed. As a result of China limiting the export of Liquid-M, China has not been invited for Q4 meetings.

surprised when they heard about China's PTDM. Nevertheless, they all urged for a more intensive collaboration and a new meeting on the short term.

One of China's main goals in the 2038 conflict was to "test" some of its newly developed technologies. China had not foreseen that the 2038 conflict would end so fast. China also expected interference in the conflict from some of its peer adversaries. Throughout the conflict, China had recognized that the decision making cycle of the international community and some of the major countries could not compete with China's tempo of operations across all the dimensions. Nevertheless, China acknowledged that it was not fighting a peer opponent. In the two years following of the conflict, China specifically focused on the further development of its quantum sensing based military capabilities. The 2038 conflict brought back a controversial discussion in the United States. Since 2018, after the long-time presence in Iraq and Afghanistan with the main focus on Counter Insurgency (COIN), the US Army had shifted its training focus on Large-Scale Combat Operations (LSCO). However, since the election of US president, Patrick Patriot in 2032 and mainly driven by the stock crash of 2033 and the absence of a large-scale conflict, the US Army had seen a massive reduction in its defense budget. This and the trend of capability building missions the United States Army executed around the globe, set the US LSCO doctrine under pressure. Nevertheless, the 2038 conflict was the inducement for the US Congress to raise the defense budget and to re-focus on China.

It is 2040. Besides the long-lasting tension between the two countries, the concurrence of circumstances kick-started a conflict between the United States and China. First, China denied the United States access to the far side of the moon. Therefore, the United States could not get Liquid-M on their terms. Second, the United States had discovered that China possessed 70 percent of the electricity power that was necessary for the V-cloud to function. This meant that China almost "controlled" the V-cloud, which was a danger for the V-cloud's decentralized and open access features. Third, when China had lost control of one of its QWJPs, the QWJP had accidentally sunk two US Sub Maritime Platforms (SMP).

What was seen during the US-China conflict was that China had some major advantages throughout the dimensions. In the physical dimension (land), US Robotic Warrior Platforms (RWP) were confronted with the effects of the further developed PTDM which now could manipulate time and motion for almost five "real-time" minutes, allowing Chinese QWJP to outmaneuver US RWP formations locally. Further, the PTDM technology was used as a coating on Chinese QWJP. The photon-layer based coating significantly reduced the kinetic impact of lasers and supersonic bullets on the QWJP's armor. Although regular satellite GPS signals were most of the time denied by both parties, Chinese units were able to navigate and to deploy GPS guided weapon systems with extreme accuracy because of the use of quantum sensor GPS capabilities. Furthermore, the Chinese Quantum Beam Binocular (QBB) was way more advanced than the US version. With the QBB Chinese soldiers could "look around corners" and see through walls, smoke, and inorganic material.

In the physical dimension (sea), the quantum underwater radar that the United States had installed on most of its SMPs could be seen as equal to China's version. Therefore, both countries were able to map out each other's underwater capabilities. However, China's underwater radar could be configured to locate small-sized objects, such as sea mines or small underwater WSAIRTVs.

In the physical dimension (air), US weapon systems such as AI Robotic Swarms (AIRS) and the outdated F-35 fighter were easily detected at considerable distance by China's deployed Mobile Quantum Radar Stations (MQRS) which was recently added in support of China's Integrated Air Defense System.

The cyberspace dimension especially the V-cloud was heavily contested by both China and the United States. Since a large part of the global population spent their time in the V-cloud, the V-cloud was seen most important to win one's opinion and support. Notwithstanding, the V-cloud existed for just a few years, this was seen as one of the most innovational dimensions since the invention of the internet in the 1990s. Both countries were still in the phase of finding out how to use the V-cloud to one's advantage.

Besides the fact that China intended to build a small base on the far side of the moon, the space dimension remained relatively uncontested. Both countries had deployed multiple swarms of satellites to gain a favorable information position. China's Spaceborne Quantum Sensor Satellite (SQSS) was still under construction. Furthermore, world leaders successfully convinced the leadership of both countries not to use the space dimension for offensive operations. Notwithstanding this small success, the next challenge for the international community was to put pressure on both countries to stop this conflict and more specifically, convince the United States not to use nuclear weapons. Some US politicians had shown strong rhetoric in support for the use of nuclear weapons or a universal quantum computer attack to end this conflict.

Scenario 3 Implications

1. Armies that incorporate the potential of quantum technology will have a significant advantage over an opponent that do not possesses this capability.
2. Quantum sensors will change warfare at the tactical and operational level of war.
3. Quantum sensors can make stealth capabilities obsolete.
4. The deployment of quantum sensors in the space dimension can enhance data collection and provide an opportunity for a quantum satellite missile defense system.
5. The development of quantum technology breakthroughs has to be closely monitored globally to prevent a surprise attack by an adversary (country or organization).

Chapter 5: Conclusion

> The future is going to happen! The choice we have is whether we will lead our way into it, or be surprised by it at some point in the future.
>
> —General John M. Murray, Commanding General, Twitter Army Futures Command

The evolution in knowledge and expertise of quantum mechanics and its application for quantum technologies—such as quantum computing, quantum communication, and quantum sensing—has challenged the perception of daily reality. It will not occur overnight that the possibilities of what quantum technology can offer are fully understood. Although quantum technology is still in its infancy, quantum technology is an emerging technology that has the potential to reshape the world and provokes a new arms race. The United States and China both recognize the importance of quantum technology for military application. Quantum computers, quantum communication, and quantum sensors will significantly change the character of warfare.

The purpose of this monograph was to investigate the potential importance of quantum technology in future warfare. This monograph briefly discussed quantum mechanics. Further, it analyzed quantum computing, quantum communication, and quantum sensing. Finally, the research presented three scenarios where the military application of quantum technology came to fruition.

The analysis of quantum technology showed a variety in the development of quantum computers. The universal quantum computer is the ultimate quantum computer. Universal quantum computers solve problems faster and can simultaneously execute difficult mathematical calculations. Moreover, quantum computers can break codes and advance AI significantly. Quantum communication allows secure communication even over vast distances and throughout the dimensions. Based on the principle of quantum entanglement even teleportation of materials can become a reality. Quantum sensors allow more accurate navigation, position determination, and timing. Furthermore, quantum sensors disturb the traditional paradigm of radar and stealth.

The scenarios can provide us a peek behind the curtain of what future warfare looks like when one fully harnesses quantum technology. At the tactical level of warfare, quantum technology will integrate into military equipment such as personal gear, weapon (systems), vehicles, and platforms (e.g. UAV, and robots). At the operational level of warfare, quantum technology affects operations throughout all the dimensions. Quantum technology facilitates data gathering and analyzing, and fastens the Observe Orient Decide Act (OODA) loop (e.g. quantum computers, and AI). In time, quantum technology will change the existing paradigm of organizing and employing military forces, since time and motion will be malleable (e.g. teleportation). At the strategic level of warfare, quantum technology offers new options for deterrence and hybrid warfare (e.g. the combination of (un) conventional warfare with cyber warfare). At the policy level, a whole of quantum approach facilitates the further development of quantum technology and its integration in all the elements of national power. Furthermore, the weaponization of quantum technology needs a discussion on the ethical dilemmas of autonomous weapon systems and human decision making guided by artificial intelligence. Military leaders should embrace the opportunities quantum technology offers for future military application. However, the possibilities of this new technology first needs to be understood and to be incorporated in education, training, and future force development.

Although quantum technology will have its implications for each dimension and warfare in general, the most significant importance of quantum technology will be its function to interweave multiple dimensions (e.g. physical-temporal-virtual), forcing a different cognitive approach and suggesting new military realities.

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