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Major William DeLeal, USMC

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Marine Corps University
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14. ABSTRACT
There are two interrelated problems in future conflict settings of concern to intelligence organizations: analytic challenges Big Data presents and cyber threats. Unprecedented data production is outpacing human and machine analytic capacity, while proliferating technology is increasing adversarial capability to penetrate communications networks. In future conflict, intelligence organizations will struggle analytically with Big Data using inadequate traditional computing which is vulnerable to cyber intrusion, and communicate finished intelligence via mediums likewise vulnerable to intrusion. Use of traditional analytic and encryption technologies in future conflicts would signal an inability or unwillingness to levy advancing technologies to increase intelligence analysis capacity and data protection. Among developing technologies, quantum-based computing and artificial intelligence, and quantum encryption present solutions to these two problems. Considering the unprecedented potential of quantum technology over the next 10-15 years, the Marine Corps and other military Service intelligence entities should develop an integrated quantum-traditional computer architecture that would generate human-AI analytic capabilities and quantum encryption to protect intelligence communications networks.

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United States Marine Corps
School of Advanced Warfighting
Marine Corps University
3070 Moreell Avenue
Marine Corps Combat Development Command
Quantico VA 22134

FUTURE WAR PAPER

A Quantum Future: Tiny Solutions to Big Intelligence Challenges in Future Conflict

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MASTER OF OPERATIONAL STUDIES

Major Bill DeLeal

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DISCLAIMER

"Many intelligence reports in war are contradictory; even more are false, and most are uncertain."

-Carl Von Clausewitz[1]

I – A Future Conflict Scenario: Two Problems for Intelligence Analysis and Data Protection

The year is 2030, and the US is at war on a large scale in the Pacific region. A Marine Intelligence Operations Center (IOC)[2] *and various stateside intelligence entities provide intelligence support to a Marine Expeditionary Force (MEF) conducting multi-dimensional combat operations. Over the course of three days of combat, hundreds of human and technological Intelligence, Surveillance, and Reconnaissance (ISR) nodes produce nearly one hundred terabytes of raw data for processing by the IOC. Over the same period, non-military entities such as the Internet and regional opposition groups produce one thousand terabytes of relevant data in multiple languages and varied data formats.*[3] *These collective data sets are the equivalent of 341,000,000 photos, 110,000,000 ten-megabyte Word documents, 1,100,000 hours of video, and 18,700,000 song-length audio recordings.*[4] *This exponential growth of information, otherwise known as Big Data,*[5] *has a relevance to the operational environment (OE)*[6] *that intelligence organizations cannot dismiss.*

Overwhelmed by the volume, variety, and velocity of Big Data, intelligence analysts in the IOC labor through the data using traditional computers and software while under unwavering time constraints to produce intelligence estimates. They sift through images, documents, video, and other forms of data for key quantitative patterns and qualitative themes, often missing correlations and dismissing data parts reductively at the expense of understanding holistically. Human factors, laborious software applications, procedural requirements, language translation, and demands to collaborate with stateside entities delay the intelligence analysis and production process. Denying the limitations of human-machine information processing *capacity, decision makers demand intelligence inputs long before the relevant data is analyzed and synthesized holistically into finished intelligence.*

The IOC distributes two unfinished intelligence estimates and three targeting packages leaving more than half of the collected data unprocessed. These products are disseminated to nearly one hundred subordinate and lateral units via secure communications using traditional encryption algorithms. They represent both a partial understanding of the enemy and US intent to employ combat power against enemy units in a specific time and place. The enemy intercepts a number of these transmissions, and gains advantage by executing deception operations meant to confirm their opponent's faulty, incomplete analysis. Simultaneously, a private organization penetrates the IOC's satellite-based cloud storage network and posts the targeting products on the Internet, negating an opportunity to remove high value targets from the battlespace, and exposing US intelligence collections sources and analytic methods.

This fictitious series of events demonstrates two interrelated problems in future conflict settings for intelligence organizations: analytic challenges Big Data presents and susceptibility to cyber intrusion by enemies and opportunistic third parties. The unprecedented growth of data production is outpacing human and machine analytic capacity, while the generally unbounded proliferation of technology is increasing adversarial capability to penetrate communications networks. In future conflict, intelligence organizations will struggle analytically with Big Data using inadequate traditional computing which is vulnerable to adversarial intrusion, and communicate finished intelligence via mediums likewise vulnerable to intrusion.

Continued use of traditional analytic and encryption technologies in future conflicts would signal an inability or unwillingness to levy advancing technologies to increase intelligence analysis capacity and data protection. Among developing technologies, quantum-based computing and artificial intelligence (AI), and quantum encryption present solutions to these two problems. Considering the unprecedented potential of quantum technology over the next 10-15 years, the Marine Corps Intelligence, Surveillance, and Reconnaissance Enterprise (MCISR-E) and other military Service intelligence entities should develop an integrated quantum-traditional computer architecture that would generate human-AI analytic capabilities and quantum encryption to protect intelligence storage and communications networks.

II – Big Data: What is the Big Deal?

Big Data is a common term used to describe "a massive volume of both structured and unstructured data so large it is difficult to process using traditional database and software techniques."[7] It is characterized by an unprecedented volume, variety, velocity (or rapidity), and accessibility of data and information.[8] In assessing the breadth of recent Big Data production, IBM estimated the need for 4.4 million data scientists to address the available data and information on the Internet in 2015.[9] To illustrate the size increase in data production in the 21st Century, the world currently generates 2.5 quintillion bytes per day (or 2.5 million gigabytes), and ninety percent of information available worldwide has been created since 2013. That astronomical acceleration compares to the 100 gigabytes generated per day in 1992, which is dwarfed by the projected 50,000 gigabytes that will be created per second (or 6,912,000,000 gigabytes per day) in 2018.[10] The volume, variety, velocity, and accessibility of Big Data will overwhelm current human and machine capacity for intelligence analysis in future conflict.

Humanity has dealt with voluminous information before, but never to this scale, rapidity of production, or accessibility.[11] Contemporary military intelligence organizations already struggle analytically with the effects of individuals and groups projecting ideas and data globally with ease via technological means, and with such systemically altering effect. Within this global context of Internet-based social media and universal access to communications mediums, proliferation of military ISR collection assets has expanded far beyond traditional intelligence collection nodes. Tactical military units that typically produce little to no intelligence data or information will host ISR platforms in future conflict. The availability of more data-producing entities in future conflict OEs – military ISR and commercial platforms – will present both opportunities for increased intelligence production, and challenges to keep pace with data production.

Given the limitations of the human mind, intelligence analysts will be incapable of comprehending holistically the vast structured and unstructured data sets in future conflict OE. Military intelligence organizations have already experienced these "ISR tipping points,"[12] a condition when analysts become exponentially incapable of completing basic analytic tasks because information flow exceeds human processing capacity. These tipping points will exist before and during major combat operations, and they will be particularly acute in the sensor-saturated OEs of future conflict.

The unrelenting pace of future conflict will compress time available for decision making, as analysts will struggle to distinguish massive irrelevant or redundant data sets, while simultaneously laboring to analyze and synthesize pertinent data sets to reduce uncertainty and inform decisions. A common response to these circumstances is to accept risk by marking large portions of collected data as unattainable analytically given their unprecedented volume, variety, and velocity. This condition emphasizes the need for advanced computational power to augment intelligence analysts.

There is no indication that Big Data production will plateau or reduce over the next 10-15 years. Population density will increase; communications technology will advance and further proliferate; megacities and mega-regions will expand and create future conflict OEs saturated with people and Big Data-producing technology. This analytic problem is accompanied by a data protection problem. Intelligence organizations will store and communicate finished intelligence via intelligence networks protected by status quo encryption technology. As cyber intrusion technologies adapt, evolve, and proliferate among potential adversaries, advanced encryption technologies must be developed and applied to protect intelligence networks.

III – From Big Data to Intelligence Production, Dissemination, and Utilization: The Necessary Role of Communications Encryption

The Marine Corps Operating Concept proposes that Marine Air Ground Task Forces (MAGTF) will operate in distributed force postures technologically enabled to send and receive intelligence data via intelligence networks.[13] ISR collection assets will proliferate to the squad and fire team levels, generating a wider intelligence collection network than previously experienced. This expansion will lead to a more symbiotic relationship between intelligence-producing entities like the IOC and tactical maneuver units. It will also require an integration of communications and storage networks that includes sending and storing unprocessed intelligence data and finished intelligence products at multiple levels of MAGTF force structure. While advantageous, this architecture presents a wider range of targets for cyber intrusion and adversarial signals intelligence efforts.

One need only conduct a modest Google search to understand the breadth and depth of the cyber threat to US government and military entities. For instance, cyber attacks against US government agencies (to include the Department of Defense) rose 1,300 percent from 2006 to 2016. Some agencies sustain tens of thousands of attacks per day, while some such as the Veterans Administration receive more than one billion per year.[14] The Department of Defense sustained 100,000 cyber attacks per day in a nine-month period from September 2014 to June 2015.[15]

Russia, China, Iran, North Korea, and other potential adversaries are advancing their cyber intrusion capabilities, and will likely continue this trend over the next 10-15 years.[16] The US employs some of the most sophisticated encryption technology in the world, but its networks will be vulnerable in future conflict scenarios while using status quo encryption technologies. Normal communications networks will be targeted, but intelligence networks pose unique and valuable targets. An adversary who penetrates these networks will have access to US understanding of combat OEs, probable intentions based on this understanding, and US intelligence collection methodologies and sources. To maintain its competitive advantage in the field of intelligence operations, the US must incorporate evolving technologies to protect its intelligence communications and storage networks with encryption that will defeat future adversarial intrusion capabilities.

The analytic challenges posed by Big Data are ultimately linked to technology. It is via technology that intelligence analysts will interface with software to manipulate Big Data for intelligence purposes. They will produce intelligence that will be stored and communicated on computers and interconnected servers that will be vulnerable to persistent cyber intrusion efforts. These two problems share a common solution in the form of quantum technology.

IV – Quantum Technology Now and in the Future: From Theory to Practical Capabilities

Einstein referred to an element of quantum mechanics as "spooky action at a distance."[17] Echoing this sentiment, renowned physicist Richard Feynman remarked, "If you think you understand quantum mechanics, you do not understand quantum mechanics."[18] Considering the complex nature of quantum mechanics, a brief explanation of its fundamentals is necessary to understand its potential to solve the problems of Big Data analysis and cyber intrusion threats in future conflict.

Quantum computers exist in 2017, but not in widely distributed use. Government agencies and a number of private companies are experimenting with quantum computers, as well as running quantum simulations on traditional computers to develop quantum technology and AI. Whereas traditional computers use bits to execute algorithms for data manipulation, quantum computers use quantum bits known as *qubits*.[19] Bits and qubits hold binary values (1s and 0s), but a qubit can be in multiple states, simultaneously holding numerous binary values at the same time. This *superposition*[20] allows a qubit to hold a more sharply exponential amount of information than a bit. For example, five qubits can store and process as much data as 32 bits; 10 qubits possess processing power of 1,000 bits; and a mere 300 qubits deliver potential storage and processing power of as many bits as there are atoms in the universe (a vast number that exists somewhere between 10^{78} and 10^{82}).[21] This unprecedented computer processing power demonstrates one aspect of why quantum computing and AI should be adopted for use in intelligence analysis of Big Data.

The private company *D Wave*[22] is a leader in quantum computing, and is developing quantum technology with NASA's Quantum Artificial Intelligence Lab, Google, the US Navy, and others. Demonstrating quantum computing potential for future military intelligence use, *D Wave* manipulated 28 qubits in 2007; 128 qubits in 2011; 512 qubits in 2013; and 1,000 qubits with its *D Wave 2X* computer in 2016.[23] Their developmental progress mimics Moore's Law,[24] which projects a doubling of processing power every two years. At that pace, *D Wave* (or other entities that develop in parallel with their progress) will develop computer-processing power capable of manipulating up to 256,000 qubits by 2030.

To put that exponential processing power into perspective, a quantum computer operating on 512 qubits (500,000 times faster and more efficient than 128 qubits) can test more than 10^{78} probabilities of a defined quantitative problem.[25] Compared to a traditional computer using bits, a quantum computer operating on 1,000 qubits could manipulate 21,000 numbers simultaneously to solve analytic problems; a traditional computer would require an enormous number of bits to perform this operation.[26] This unprecedented computational potential is not confined to quantitative problems based on numbers. The *D Wave 2X* computer capabilities include AI development, optimization solutions to combinatorial problems,[27] pattern recognition, and anomaly detection in large data sets.[28] The intelligence-related applications of these capabilities relate directly to the challenges of Big Data, namely sifting through vast and diverse sets of data to determine relevance to intelligence questions and production requirements.

Qubits can also be connected to one another, regardless of distance. This *entanglement*[29] means that when the state of a quantum particle changes, its entangled partner also changes regardless of distance. This *entanglement* principle not only influences qubit capacity for data storage and manipulation, it is the basis for quantum encryption. Whereas traditional Public Key Cryptography (PKC) relies on mathematical algorithms to prevent intrusion, quantum encryption uses the quantum mechanics principles of *entanglement* and *superposition* to transmit information as encryption keys in quantum states.

In Quantum Key Distribution (QKD), these keys are transmitted using quantum photons whose quantum state would be altered if observed in an attempt to intercept or hack the communication. In contrast to PKC algorithms that can be intercepted and decrypted, the quantum state of the photon (i.e., the encryption key) is theoretically unknowable to anyone who did not initiate the key. Thus, QKD promises an unprecedented level of communications and storage security for intelligence networks. As an indication of QKD's potential, China deployed its quantum-encrypted *Micius* satellite into orbit in August 2016.[30] China's Academies of Sciences announced in January 2017 that the satellite successfully transmitted to two ground stations using quantum encryption. These ground stations, 1,200 kilometers apart, repeated the transmission between themselves. These events verified the viability of ground-to-satellite and ground-to-ground communications encrypted by quantum technology.[31]

Public and academic discussions of when and how QKD and quantum computers will become normative and commercialized is both ambitious and contentious.[32] What is clear in this dialogue is that quantum technology is no longer a matter of theory, and is instead a question of engineering. As of late 2016, private organizations and government entities were investing in quantum technology for mercantile, business, environment, civil functions, security, and military applications. These actors include the European Union (EU), US, China, Britain, France, Japan, Google, Microsoft, IBM, NASA, and Lockheed Martin; nearly every globally-renowned university is also experimenting with quantum technology.[33] Major financial commitments include $440 million by Britain in 2015, and multiple billions of dollars by the EU, China, and the US since 2009. There are a number of indications that suggest China is outpacing any government in developing quantum technology.[34] Quantum computing will, if not revolutionize, significantly shape the future of computing. The US military should be counted among those who commit resources to develop quantum technology, specifically for intelligence purposes. To this end, it is necessary to examine potential intelligence-related functions and capabilities of quantum computing and AI.

Google, IBM, NASA, the Director of National Intelligence's IARPA, and other entities are currently exploring AI derived from quantum technology.[35] AI is characterized as a machine that is able to perform tasks such as visual perception, image interpretation, or decision making that normally requires human intelligence.[36] AI powered by the unparalleled capabilities of quantum computing could produce unprecedented human-machine analysis of intelligence problems and Big Data, and generate asymmetric advantages in the fields of information, intelligence, and military decision making.

For example, quantum-based AI could examine hundreds of terabytes of Big Data for word- and image-based patterns to discern enemy intent, or to develop targeting recommendations of critical enemy force structure at a fraction of the time it would take a human or current analysis software. While executing this function, quantum-based AI could simultaneously translate relevant videos and documents into English from foreign languages.[37] Current technologies typically translate foreign languages word-for-word and struggle with idioms, grammatical nuance, and illogical sentence structures. Quantum-based AI could theoretically translate and interpret passages accurately as would a competent human linguist. As quantum-based AI "swallows the complexity of Big Data whole,"[38] human analysts would become free to focus on qualitative analysis and other matters related to operations-intelligence integration. There are further quantum technology uses for intelligence analysis.

The *D Wave* Company and others have developed capacity to solve combinatorial optimization via *quantum annealing*.[39] An optimization method that can be used for probability analysis, pattern recognition, and language translation, annealing is capable of solving a number of intelligence-related problems. An example is the "Travelling Salesman" NP-complete problem.[40] In this problem, an analyst must determine the most optimal route a salesman should take to visit a predetermined number of cities. When considering the host of unstable variables of geography, weather, travel modes, traffic, crime, fuel prices, and socio-political considerations, an example including travel within 15 cities presents over 40 billion potential route combinations. Determining the best route is an optimization problem that quantum-based AI can solve in less than one second of calculation, 3,600 times faster and more precise than current supercomputers.[41] The intelligence application of such a capability relates to determining optimal avenues of approach when maneuvering combat formations, or validating operational courses of action during military campaign design.[42]

Quantum computers can also conduct topological data analysis (TDA).[43] A branch of statistics, TDA can be used for deep analysis of large data sets inherent in Big Data to estimate the character of relevant variables in a conflict OE such as geographic features or operational maneuver patterns of military formations. Additional intelligence analysis functions that can be solved by quantum-based AI include probability analysis, imagery identification and analysis, ISR full-motion video compression, and optimizing outcomes of potential courses of action. This last function relates to analyzing factors and variables of a conflict OE to determine an optimal course of action (a function related to *What If?*[44] intelligence analysis), intelligence support to targeting, and Red Cell support to the Wargaming step of military planning processes. When considering the breadth of intelligence analysis functions quantum computing offers in the age of Big Data, the logic of integrating quantum technology into intelligence systems is clear.

While the quantum future is promising, it is not without difficulties and uncertainties. Some hurdles that must be overcome include translating qualitative problems into language quantum computers understand, as many current quantum functions are purely mathematical. The potential of quantum processing power and encryption has generated committed skeptics. Among them, Scott Aaronson maintains a blog posing questions ranging from whether the processing power will be capable of anything more than writing computer code, to whether qubits can actually be manipulated.[45] He and a number of scholars criticized the *D Wave* Company prior to 2015 by claiming its professed capabilities were overstated, and that they could not manipulate more than a few qubits. Skeptics also doubted the viability of quantum-based encryption. These doubts were voiced before China deployed its quantum-encrypted satellite in August 2016, and confirmed successful use of quantum encryption in January 2017.[46]

Another issue of quantum technology relates to the difficulty of manipulating particles at the quantum level. Qubits operate in ways that defy conventional human understanding of the physical world. The engineering requirements to control these particles are expensive and, at current capability, large. For a qubit to retain any data assigned to it, the particle must remain coherent. The issue of *coherence*[47] requires a quantum superconductor to place qubits in a near absolute zero temperature (-459.4 degrees Fahrenheit). *D Wave* accomplished this in its *D Wave 2X*, creating an environment 180 times colder than interstellar space with pressure 10 billion times lower than Earth's atmospheric pressure.

It is within this contained space that qubits can be controlled to behave more like an electron and retain data assigned to them. When qubits operate otherwise, they can quickly become decoherent and lose data or viability as an encryption method. This engineering requirement is expensive to build and maintain; the *D Wave 2X* reportedly cost $10 million to build. Because of its size, power requirements, and maintenance demands, the system would not be ideal for military deployment to a combat zone. Considering these size and physical environment requirements, a hub-and-spoke intelligence systems architecture is the most practical design model to generate quantum-traditional computing and encryption capability to address the problems of Big Data and cyber threats in future conflict.

V – Quantum Technology and Military Intelligence Operations: A Hub-and-Spoke Model of Quantum and Traditional Computing Integration

Quantum computing and encryption will continue to develop in the coming decades, but will not likely replace traditional computers and PKC outright. An optimal method of integrating quantum technology is a hybrid quantum-traditional computing design model where a quantum-computing hub would extend quantum computing, AI, and quantum encryption to a network of traditional computers. Current hub-and-spoke Wide Area Network (WAN) computer architecture configurations predominantly deliver Cloud Computing storage space, secure net connectivity, and access to human-to-human collaboration software such as SharePoint from a central hub to remote sites. The hub typically consists of a large server connecting a network of computers via access points to the Internet and other communications (e.g., satellite or fixed-site land lines). This server can host Cloud-based storage or maintain data-storage repositories for remote accessing. Figure 1 illustrates an example of a quantum hub extending quantum computing, AI, and quantum encryption to local and remote traditional computers.

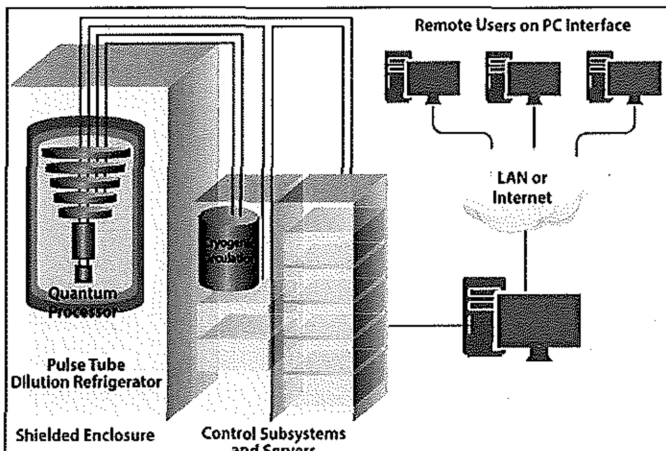

Figure 1: Quantum Superconductor and Processor Connected to Classical Computers. *From dwavesys.com.*

The ideal locations for these quantum-traditional computing hubs would be at fixed-site intelligence analysis centers such as the MAGTF Intelligence Centers (MIC) resident at each MEF headquarters, or the Marine Corps Intelligence Activity (MCIA) in Quantico, Virginia. These quantum hubs would differ from their contemporary versions because they would deliver unprecedented quantum-based analytic computing power to address the challenges of Big Data, a capability not currently in practice. Further, they would provide the basis for AI that would serve as the primary source of human-machine hybrid interfacing for analytic judgment and support to military decision making. Finally, they would be the central point to generate QKD for encryption of local and deployed intelligence communications and storage systems (see Figure 2).

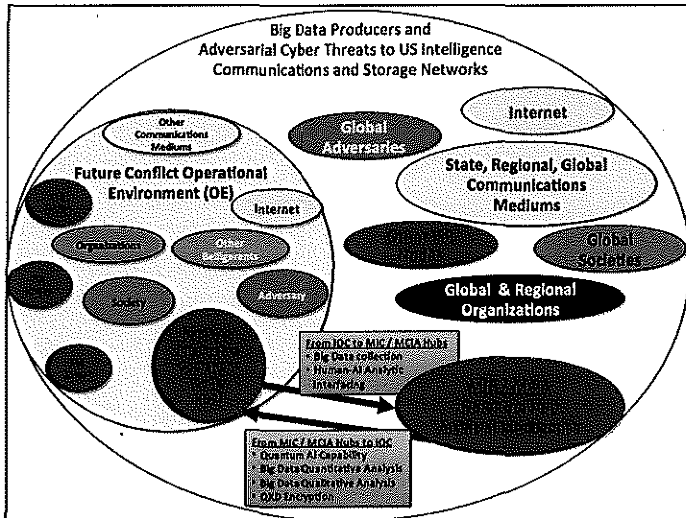

Figure 2: Big Data production and cyber threats in a hypothetical conflict OE & global environment. Supporting & supported relationships between a deployed IOC & MIC/MCIA quantum-AI-encryption hubs.

Intelligence operations and analysis doctrine would need to adapt to this new capability. IOCs that deploy with Marine Expeditionary Brigade- (MEB) or MEF-level MAGTFs would register their expeditionary servers and traditional computers within this hub-and-spoke network. While supporting tactical and operational combat operations, the various sub-components of the IOC such as the All-Source Fusion Cell would prioritize quantitative and qualitative analysis tasks to be conducted by the forward-deployed IOC, its respective MIC, and MCIA. Those tasks assigned to the MIC or MCIA would constitute the bulk of Big Data problems, and be addressed by AI at the quantum hub. As needed, the IOC would conduct human-to-human and human-to-machine interfacing with the quantum hub from a remote site for qualitative analytic tasks and production requirements that support decision makers in the MEF or MEB. As this wide spectrum of analysis tasks is ongoing, the fixed-site quantum hub would continue to provide QKD encryption capability to intelligence communications and storage networks.

The full technical, procedural, and doctrinal integration of quantum computing and AI for Big Data analysis and QKD for encryption is no simple matter. Considering the extensive inventory of pre-existing traditional computers and PKC encryption hardware and software currently in use for intelligence purposes, the physical integration of quantum technology could take years once it becomes widely available. The procedural integration of interacting with a thinking quantum-powered AI machine will also take time for analysts (and the decision makers they support) to become comfortable with. Nevertheless, the quantum technology capabilities presented are appropriate considering the scope of challenges presented by the Big Data analysis and cyber threat problems identified in this paper.

VI – Conclusion

The wisdom of Thucydides and Clausewitz addresses the nature of war, which will endure in its friction-induced complexity and uncertainty. The character of future conflict will be shaped significantly by information and technology; both are matters of significant concern to intelligence organizations. Good intelligence analysis makes the complex and uncertain, at best, comprehensible.[48] To this end, every effort and opportunity must be taken to leverage advancing technologies prior to conflict.

Quantum technology is a contemporary reality that governments, private organizations, and potential adversaries are experimenting with. If current trends continue, it will become a tool granting asymmetric advantage in future combat OEs to those who invest in its development and integration. As the US commits resources to ensure advantages in future conflicts over the coming decades, quantum technology is a necessary and practical addition to its arsenal of intelligence assets that will minimize the impact of Big Data saturation and thwart adversarial cyber intrusion efforts into intelligence networks.

[1] Carl Von Clausewitz, *On War,* edited by Michael Howard, Peter Paret, and Bernard Brodie (Princeton, N.J.: Princeton University Press, 1984), 117.

[2] The Intelligence Operations Center (IOC) is the primary intelligence node at Marine Expeditionary Force and Brigade levels. The IOC concentrates specialized intelligence capabilities from the radio battalion, the intelligence battalion, and the force reconnaissance company under this centralized direction to facilitate unity of effort, effective employment of limited assets, and the collection and production of all-source intelligence. Headquarters Marine Corps, *Intelligence Operations,* MCWP 2-10 (Washington, DC: 2 May 2016), 4-1.

[3] One terabyte is equal to 1,000 gigabytes of data. One petabyte is equal to 1,000,000 gigabytes of data. A 2013 estimate suggested there were 1.2 million terabytes of data held on the Internet by only four companies: Google, Amazon, Microsoft, and Facebook. As of 2016, 2.5 quintillion bytes of data are created each day. IBM, "Bringing Big Data to the Enterprise," (accessed 22 December 2016), https://www-01.ibm.com/software/data/bigdata/what-is-big-data.html; Gareth Mitchell, "How Much Data is on the Internet?" *Science Focus,* 23 January 2013, http://www.sciencefocus.com/qa/how-many-terabytes-data-are-internet.

[4] PC Ninja estimated that one terabyte of data would equal 17,000 hours of music, 1,000 hours of video, and 310,000 photos. PC Ninja, "How Much Can A 1 TB Hard Drive Hold?" *PCNinja,* accessed 4 February 2017, http://www.pcninja.us/how-much-can-a-1-tb-hard-drive-hold/.

[5] This paper references three similar definitions of Big Data to explain its relevance and problematic nature to analytic intelligence operations in future conflict situations. The first definition is from Vangie Beal of *Webopedia: "Big Data is a phrase used to mean a massive volume of both structured and unstructured data that is so large it is difficult to process using traditional database and software techniques. In most enterprise scenarios the volume of data is too big or moves too fast or it exceeds current processing capacity.*" The second definition is from the Merriam-Webster Dictionary: "*Big Data is an accumulation of data that is too large and complex for processing by traditional database management tools.*" The third definition is from Microsoft: "*Big data is the term increasingly used to describe the process of applying serious computing power—the latest in machine learning and artificial intelligence—to seriously massive and often highly complex sets of information.*" Vangie Beal, "Big Data," accessed 4 February 2017, http://www.webopedia.com/TERM/B/big_data.html; Merriam-Webster, "Big Data," accessed 4 February 2017, https://www.merriam-webster.com/dictionary/big%20data; Microsoft, "The Big Data Conundrum: How to Define It?" *MIT Technology Review, 3 October 2013,* https://www.technologyreview.com/s/519851/the-big-data-conundrum-how-to-define-it/#comments.

[6] Operational Environment is described as, "*...the composite of the conditions, circumstances, and influences that affect employment of capabilities and bear on the decisions of the commander. It encompasses physical areas and factors (of the air, land, maritime, and space domains) and the information environment (which includes cyberspace). Included within these are enemy, friendly, and neutral systems that are relevant to an operation. The nature and interaction of these systems will affect how the commander plans, organizes for, and conducts operations.*" Joint Chiefs of Staff, *Joint Operations,* JP 3-0 (Washington, DC: Joint Chiefs of Staff, 11 August 2011), xvi; Joint Chiefs of Staff, *Joint Intelligence Preparation of the Operational Environment,* JP 2-01.3 (Washington, DC: 16 June 2009), I-2.

[7] Beal, "Big Data."

[8] Joint Chiefs of Staff, *Joint Intelligence,* JP 2-0, (Washington, DC: 22 October 2013), I-1; Diya Soubra, "The 3Vs that Define Big Data," *Data Science Central,* 5 July 2012, http://www.datasciencecentral.com/forum/topics/the-3vs-that-define-big-data.

[9] IBM, "What is Big Data," accessed 3 November 2016, http://www.ibm.com/big-data/us/en/.

[10] VCloud News, "Every Day Big Data Statistics," 5 April 2015, accessed 8 October 2016, http://www.vcloudnews.com/every-day-big-data-statistics-2-5-quintillion-bytes-of-data-created-daily/.

[11] Ann M. Blair, *Too Much to Know: Managing Scholarly Information before the Modern Age* (London: Yale Publishing, 2010).

[12] Isaac R. Porche III, Bradley Wilson, Erin-Elizabeth Johnson, Shane Tierney and Evan Saltzman, *Data Flood: Helping the Navy Address the Rising Tide of Sensor Information* (Santa Monica, CA: RAND Corporation, 2014). http://www.rand.org/pubs/research_reports/RR315.html.

[13] United States Marine Corps, *Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century,* (United States Marine Corps: Washington, DC: September 2016), 5-7.

[14] Suman Bhattacharyya, "Cyber Attacks Against the US Government Up %1,300 Since 2006," *The Fiscal Times,* June 22, 2016, http://www.thefiscaltimes.com/2016/06/22/Cyberattacks-Against-US-Government-1300-2006.

[15] Office of the Secretary of Defense, "Department of Defense Cyber Security and Compliance Initiative," Memorandum for Secretaries of the Military Departments, 30 September 2015.

[16] American Foreign Policy Center, "Strategic Primer: Cybersecurity, Current Capabilities and Emerging Threats," *Defense Technology Program, Spring 2016, Vol. 2.*

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