FROM SCIENCE AND TECHNOLOGY TO INNOVATION DIPLOMACY: THEIR FUTURE AND THE RELATIONSHIP WITH INTERNATIONAL SECURITY

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This article consists of a theoretical essay, essentially supported by bibliographical research strongly complemented with our own experience in most subjects and it has a qualitative and exploratory bias. It consists of an introduction to the research object where we make a broad approach in a world undergoing constant changes specially related to scientific and technical aspects of science, technology, and innovation diplomacy (ST&I) during the last two decades. Among many others, to address the issue we have chosen some relevant areas like artificial intelligence (AI), internet of things (IoT), cyber diplomacy, and quantum technology. We also make the linkages between the ST&I aspects and diplomacy, and its relationship with some aspects of military technologies. In this aspect we reinforce the relevance – a point of concern – of the proliferation of military technologies by scientific collaboration, commercial trade, or other mechanisms. Despite the traditional scientific collaborations between thousands of groups all around the world, we show the importance of considering that both enemies and potential enemies, should be avoided of having access to certain critical and sensitive technologies. In this way, we show its relevance and importance as a strategic planning in national defense essential for the sovereignty of any country and international security.

Keywords: science, technology and innovation; disruptive technologies; cyber diplomacy; scientific collaboration.

DA CIÊNCIA E TECNOLOGIA À DIPLOMACIA DA INOVAÇÃO: SEU FUTURO E A RELAÇÃO COM A SEGURANÇA INTERNACIONAL

Este artigo consiste em um ensaio teórico, essencialmente apoiado por pesquisas bibliográficas fortemente complementadas com nossa própria experiência na maioria dos assuntos, e tem um viés qualitativo e exploratório. Consiste em uma introdução ao objeto de pesquisa em que fazemos uma abordagem ampla em um mundo que passa por constantes mudanças especialmente relacionadas a aspectos científicos e técnicos da ciência, tecnologia e inovação (CT&I) nas últimas duas décadas. Entre muitos outros, para abordar o assunto, escolhemos algumas áreas relevantes como inteligência artificial (IA), internet das coisas (*internet of things* – IoT), diplomacia cibernética e tecnologia quântica. Também fazemos as ligações entre CT&I e a diplomacia, e sua relação com alguns aspectos das tecnologias militares. Nesse aspecto, reforçamos a relevância – um ponto de preocupação – da proliferação de tecnologias militares por colaboração científica, intercâmbio comercial ou outros mecanismos. Apesar das colaborações científicas tradicionais entre milhares

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de grupos em todo o mundo, mostramos a importância de considerar que tanto inimigos quanto potenciais inimigos devem ser evitados de ter acesso a certas tecnologias críticas e sensíveis. Dessa forma, mostramos sua relevância e importância como um planejamento estratégico em defesa nacional essencial para a soberania de qualquer país e a segurança internacional.

Palavras-chave: ciência, tecnologia e inovação; tecnologias disruptivas; diplomacia cibernética; colaboração científica.

DE LA CIENCIA Y LA TECNOLOGÍA A LA DIPLOMACIA DE LA INNOVACIÓN: SU FUTURO Y LA RELACIÓN CON LA SEGURIDAD INTERNACIONAL

Este artículo consiste en un ensayo teórico, esencialmente apoyado por la investigación bibliográfica fuertemente complementada con nuestra propia experiencia en la mayoría de los temas y tiene un sesgo cualitativo y exploratorio. Consiste en una introducción al objeto de investigación donde hacemos un acercamiento amplio en un mundo sometido a constantes cambios especialmente relacionados con aspectos científicos y técnicos de la ciencia, tecnología e innovación (CT&I) durante las últimas dos décadas. Entre muchas otras, para abordar el tema hemos elegido algunas áreas relevantes como inteligencia artificial (IA), internet de las cosas (*internet of things* – IoT), diplomacia cibernética y tecnología cuántica. También establecemos los vínculos entre los aspectos de CT&I y la diplomacia, y su relación con algunos aspectos de las tecnologías militares. En este sentido reforzamos la relevancia – un punto de preocupación – de la proliferación de tecnologías militares a través de colaboración científica, intercambio comercial u otros mecanismos. A pesar de las colaboraciones científicas tradicionales entre miles de grupos en todo el mundo, mostramos la importancia de considerar que tanto los enemigos como los enemigos potenciales, deben ser evitados de tener acceso a ciertas tecnologías críticas y sensibles. De esta manera, mostramos su relevancia e importancia como una planificación estratégica en defensa nacional esencial para la soberanía de cualquier país y la seguridad internacional.

Palabras clave: ciencia, tecnología e innovación; tecnologías disruptivas; diplomacia cibernética; colaboración científica.

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1 INTRODUCTION

Nina V. Fedoroff,[4] former Science and Technology Adviser for the American government in 2009, defined *science diplomacy* as the use of scientific collaborations among nations to address the common problems facing 21st century humanity and to build constructive international partnerships. From this, we can directly extend this definition to the most complete concept of *science, technology, and innovation diplomacy* (ST&I).

4. Science and Technology adviser to the Secretary of State and to the administrator of the U.S. Agency for International Development (USAID) at the United States Department of State, during 2009.

In all forms of ST&I diplomacy, it is important to be clear when science, technology and innovations end, and politics begins. At the Royal Society (AAAS) meeting in 2010, Professor John Beddington (United Kingdom's Chief Scientific Adviser) said that scientific collaboration could provide a sort of a blueprint for international diplomacy but warned of possible dangers for those scientists who wish to engage in the diplomatic game.[5] Off course that means that science ends up being used for political ends. On the other hand, Chris Whitty (United Kingdom's chief scientific adviser at the Department for International Development), authorized scientific collaboration with developing countries if the goal is to transform the lives of the poor people, only. Moreover, some governments have strict guidelines for how scientific advice is used in national policymaking, which can also be applied to the international field.

It is a must to mention here about the practical barriers to ST&I exchange. The constraints to ST&I diplomacy include regulatory barriers, such as visa restrictions and security controls especially after September 11th, 2001. United States and United Kingdom have been limiting the opportunities for visiting scientists and scholars, particularly from Islamic countries. Such understandable policies shut out talented scientists and hinder opportunities to build scientific relations between countries. However, those policies could also be avoiding new terrorist attacks. Security controls can also prevent collaboration on certain scientific subjects, such as nuclear physics and microbiology. That is one of the prices of some particular forms of terrorism. Although these policies are based on legitimate concerns over the dual use potential of some scientific knowledge, they should also take into consideration the diplomatic value of scientific partnerships in sensitive areas to help rebuild trust between nations what is not going to be an easy task.

In the middle of 2017, Leijten published an excellent explorative article intitled *Exploring the Future of Innovation Diplomacy* (Leijten, 2017). He considers that science diplomacy links the two policy domains of foreign affairs and science policy. According to him, competitive thinking, and the ways in which this affects global challenges are now putting the globalization trends in ST&I under pressure. On the other side, new populist governments go in the opposite direction favoring the growth of politics of de-globalization and thus, leading to introduce strong changes in the roles diplomats play. In the last decades, the focus of diplomats has already shifted from relatively neutral scientific collaborations to the technology and innovation interests of their home-countries. In this article the author explores the future roles and development of innovation diplomacy

5. Three immediate areas of opportunity for ST&I diplomacy were highlighted at the Royal Society/AAAS meeting: i) new scientific partnerships with the Middle East and wider Islamic world; ii) confidence building and nuclear disarmament; and iii) governance of international spaces like Antarctica, the high seas, the deep sea, outer space etc.

as the outcome of interactions between the evolving characteristics of ST&I providing a framework through which potential futures of innovation diplomacy can be explored.[6]

2 THE LEARNED LESSONS TO ST&I DIPLOMACY FROM THE COVID-19 PANDEMICS

A report[7] released in 2020 (in the middle of covid-19 pandemic) by the World Economic Forum, shows that we have the option of rebuilding the institutions of the past or reimagining a new multilateral system focused on science, technology, health, and the environment. It says that what we need is a new generation of leaders to build bridges between ST&I and diplomacy to address global challenges. In this case what role do ST&I and health play in diplomacy? The universal language of science more recently together with technology and innovation, has been used throughout history to build bridges and relax political tensions between nations. Looking just at the scientific evidence, scientists establish collaborations with their colleagues in any country in the world, even when their governments are not getting along.[8]

The coronavirus pandemic has highlighted the key role of science and health in understanding and addressing cross-border challenges. But for most countries, global health is not a priority. The actual crisis has exposed the lack of global leadership. Previous outbreaks[9] of *severe acute respiratory syndrome* (Sars), *swine flu* (H1N1), *Middle East respiratory syndrome* (Mers) also known as *camel flu*, and Ebola were contained through rapid multilateral action. But, as the coronavirus spreads, political divisions are only deepening. The United Nations Security Council and the Group of Seven (G7) fail to agree on joint

6. In 2019, Leijten also published *Science, Technology, and Innovation Diplomacy: a way forward for Europe. Institute for European Studies Policy*. According to the author, the second half of the 20th century was a period of steadily growing globalization of firms and growing interconnections between national economies. With the increase availability of new and cheap means of communication and changes in transportation/containers since 1980 it became increasingly easy to coordinate the global activities in production and in trade. Europe benefited from this globalization by amassing a large trade and globalization was generally seen as beneficial for everybody. They show that optimization of industrial production at a global scale created huge growth opportunities in South-East Asia, China, and South Korea and the flow of cheaper products to Europe and to the United States contributed to increasing living standards in these regions. Without any doubt, ST&I are the most transformative tools of the past fifty years. Technological developments have driven the costs of communication and processing of information down while at the same time improving on speed and processing capacity. ST&I have becoming ubiquitous, entering all sectors of society and almost all aspects of personal life. The author considers that ST&I is also playing a key role in other fields of technology, like nano-, bio- or environmental technologies, determining their speed of development and the characteristics of their applications. They mentioned that there are two developments with both having firm anchors in the basic technologies, while the first is networking of almost all aspects of life and the second is availability of data.

7. Available at: <https://bit.ly/3GxJgKt>. Accessed on: Aug. 2021.

8. These international networks can help address cross-border challenges and restore trust and win-win relationships when diplomatic relations become strained. For example, after World War II, the European Laboratory for Nuclear Research (CERN – Conseil Européenne pour la Recherche Nucléaire) facilitated the first post-war contacts between German and Israeli physicists. CERN, housing the famous Large Hadron Collider (LHC) is an excellent example of ST&I diplomacy.

9. For details about these agents, see Rahimi et al. (2020).

statements. Only after covid-19 cases rose to more than half a million in almost two hundred countries and territories, the Group of Twenty (G20) pledged to strengthen the World Health Organization (WHO). The scientific journal *Nature* has urged governments and their scientific advisers to advocate for a collective and transparent approach in the fight against covid-19. However, most of those countries lack scientific advice systems. These structures can take various forms depending on the country and the government system, but they are key to anticipating risks and ensuring that scientific evidence informs public policies. However, fortunately more and more countries are recognizing the need to integrate ST&I into their foreign policy agendas.[10]

Certainly, one of the most effective ways to advance ST&I diplomacy is giving training to the next generation of leaders to meet the challenges and opportunities of the fourth industrial revolution to maximize benefits for all and minimize common threats. These types of initiatives generate the networks of experts and the trust necessary to quickly activate international collaborations when a crisis strikes. We are deeply inside in the largest scientific communication experiment in human history. Scientists are more visible and highly valued by politicians and the public than ever. Molecular biology terms such as DNA (*deoxyribonucleic acid*), RNA (*ribonucleic acid*) or PCR (*polymerase chain reaction*) have become extremely popular, mathematical concepts of linear, exponential, and logarithmic growth are explained on primetime television, and public health and epidemiology concepts such as *#FlattenTheCurve*, *#SocialDistance*, or *#WashYourHands* have become "trending topics".

Turchetti and Lalli published in 2020 at *Nature* magazine the article *Envisioning a Science Diplomacy 2.0: on data, global challenges, and multi-layered networks*.[11] There, the term science diplomacy identifies the interactions between scientific and foreign policy communities connected to the promotion of international scientific exchanges and the provision of scientific advice on issues of relevance to more than one nation. The authors sketch the contours of a data-driven science diplomacy 2.0 that could be seen as more directly tackling these challenges in two important ways: i) a multilayered approach that integrates data and meta-data from various disciplines in order to promote greater awareness about what kind of research should actually be prioritized in science

10. The Swiss Foreign Ministry recently launched a public-private foundation to anticipate and mediate conflicts through scientific cooperation. France and Denmark have appointed ambassadors to tech industry enclaves like Silicon Valley, ushering in a new era for digital diplomacy. Chile and South Africa take advantage of their strategic position in astronomy to strengthen their global position through space cooperation. There are many more initiatives currently under development seeking to improve the science-policy interface at the national, regional, municipal, and multilateral levels.

11. Available at: <https://go.nature.com/3t9j2IF>. Accessed on: Sept. 2021.

diplomacy actions; and ii) the creation of responsible innovation observatories for operationalizing such a methodology at both national and global levels.[12]

In the beginning of 2021, Renan Silva, Gabriela Ferreira, Janina Onuki and Amâncio de Oliveira published the article[13] *The Institutional Building of Science and Innovation Diplomacy in Latin America: toward a comprehensive analytical typology*. In this work, the authors shows that ST&I diplomacy has emerged in recent years as a relevant scholarly movement and interdisciplinary research agenda internationally. This field is promoting a significant impact on the understanding of the cultural and political dynamics of Science, Technology, and Innovation implementing initiatives from local to global level. However, ST&I is growing asymmetrically around the world, setting up over a particular configuration in the so-called Global South societies.[14]

3 ST&I DIPLOMACY AND THE NEW SCIENTIFIC FRONTIERS

In 2021, Brian Burke[15] said that "The unprecedented socioeconomic challenges of 2020 demand the organizational plasticity to transform and compose the future". Nothing truer than that. Besides the examples about ST&I diplomacy given all along the text, like Human Genome Project, ozone layer recovering, CERN and the LHC, and the fighting against coronavirus pandemic, there are some others that deserve to be mentioned here. We also make the linkages between the ST&I aspects and diplomacy and its relationship with military technologies. Despite the traditional scientific collaborations between thousands of groups all around the world, we must take into account the importance of considering that both enemies and potential enemies, should be avoided of having access to certain critical and sensitive technologies. We would like to make an approach here of excellent examples of ST&I diplomacy like synchrotron radiation technologies; nuclear technology (both fusion and fission); spintronic; superconductivity; biotechnology; synthetic biology; nanobiotechnology and bionanotechnology, among many others. Because of their enormous relevance and novelty, and for an obvious question

12. Also, in 2020, Gluckman and Turekian published at *Nature* magazine the article *Rebooting Science Diplomacy in the Context of Covid-19* starting with the phrase: Science can be a common language and an important mechanism for calming geostrategic tensions. There, the authors consider that the covid-19 pandemic is amplifying preexisting tensions between the United States and China across all possible domains, including ST&I. This is happening even as global ST&I cooperation has become a central feature of public health and the development of vaccines and treatments. Does this new dynamic between the two powers accurately reflect a changed world, and could it presage greater tension to come?

13. In Frontiers in Research Metrics and Analytics, Apr. 27, 2021, available at: <https://bit.ly/3N7jiQu>. Also available at: <https://bit.ly/3N7jiQu>. Accessed on: Aug. 2021.

14. In Latin America, although ST&I is a recent, unequal, and intra-nationally fragmented process, there are important achievements that have been able to create a favorable mix of approaches, agendas, and practices in this field. In this work, authors aim to present a comprehensive analytical typology to the study of the emerging experiences of ST&I in Latin America, catching the diversity of this research agenda.

15. Editor and research vice president of the Gartner Group.

of having a limited space for the actual chapter, we will focus just in the newest and more remarkable areas: cyber diplomacy, artificial intelligence (AI), internet of things (IoT) and quantum technologies. Every one of them relative to ST&I diplomacy surely could give an independent chapter for this book. As a matter of fact, these are sensitive areas that should be more restricted when considering ST&I diplomacy. Already finding their way into modern weapons' systems, controlling the proliferation of these technologies and their misuse is a sleeper issue that will soon demand an entirely new set of diplomatic initiatives, like those developed to monitoring and control of nuclear weapons.

3.1 Cyber diplomacy

Digital world has brutally changed in the last decades where cyber espionage, cyber-attacks, hacktivism, internet censorship are now making the headlines on a regular basis. Cyberspace has become a political space battlefield, shaped by diverging interests of all kinds. If cyberspace was once a domain for technical discussions among information technology (IT) specialists only, that time is definitively over. Cyberspace has become a major locus and focus of international relations where, because of its politicization, diplomats have entered the game. In 2017, Barrinha and Renard propose to explore in their article[16] *Cyber-diplomacy: the making of an international society in the digital age* the concept of cyber diplomacy, by analyzing its evolution and linking it to the broader discussions of diplomacy as a fundamental institution of international society, as defined by the English School of International Relations. The authors argue that cyber diplomacy is an emerging international practice that is attempting to construct a cyber-international society, bridging the national interests of states with world society dynamics – the predominant realm in which cyberspace has evolved in the last four decades.[17]

Rashica from South East European University, Macedonia, published in 2018 the article intitled *The Benefits and Risks of Digital Diplomacy* (Rashica, 2021). She considers that, as a product of both globalization new public diplomacy, digital diplomacy is one of the most important tendencies of the new millennium. It is undeniable and unquestionable the strong influence on the internet and the social media of the extraordinary advances in information and communications

16. Available at: <https://bit.ly/3z7iXZO>. Accessed on: Sept. 2021.

17. These same authors, Barrinha and Renard, published another interesting article intitled *The Emergence of Cyber Diplomacy in an Increasingly Post-Liberal Cyberspace*, where essentially, they make an approach to the power relations, values, and institutions that governed cyberspace since its initial development in the 1960s. Today, conflicting visions for the future of the global internet are taking to an inevitable collision, therefore cyber diplomats must negotiate these difficult choices. According to the authors, a Huawei led-group that included China Mobile, China Unicom, and the Chinese Ministry of Industry and Information Technology proposed a significant deep revision of the internet proposing a new top-down internet protocol they called *New IP*. Faraway of these technical considerations, some people interpreted this proposal as another wider political move, which China heading that with the goal: cyberspace can no longer be dominated by the West and needs to reflect the new balance of power in the international system.

technology (ICT) which is an extensional term for IT. This new term stresses the role of unified forms of communications as well as the integration of different forms of telecommunications and computer. ICT also includes, the necessary commercial software, middleware, storage and audiovisual, that allow users to access, store, transmit, understand, and manipulate all available information. Because of the enormous advances in ICT on the internet and social media, the way of realization and presentation of diplomacy has been radically changed and is radically different from what it used to be as the traditional one.[18]

However, this irreversible process of digitization has, consequently, the arising of a new area, the *cyber diplomacy*, which is the use of diplomatic tools to address issues originated *in* and *through cyberspace*. Those issues cover a plethora of different aspects like security, economic and human rights topics, including international cybersecurity standards, internet access, privacy, internet freedom, intellectual property, cybercrime, ethical use of digital technologies, among many others.

Emily O. Goldman, in her work *Cyber Diplomacy for Strategic Competition*,[19] published very recently in June 2021 at *The Foreign Service Journal* from the America Foreign Service Association, she shows that over the past decade, adversaries have been bypassing territorial boundaries by operating *in* and *through* cyberspace to gain strategic advantage. It is undeniable that cyberspace is one of the strongest factors holding both the prosperity and security of most rich and countries not only the Unites States but also its allies. Moreover, their future depends on cyberspace in ways impossible to understand – or even to imagine – just some decades ago. Everything in every area that is important and strategic for every country uses the cyberspace and that is why cyberspace – and the whole digital environment – has probably become the most important arena for every strategic competition. It is straightforward for the governments and corporations accept at once that new

18. According to Rashica, the digital diplomacy is based on the usage of ICT, the internet, and social media, which at the same time represent its base, for the strengthening of the diplomatic relations. She proposes that knowledge about the role and importance of digital diplomacy is indispensable and through this article she intends to provide sufficient arguments to show that benefits and risks of digital diplomacy is not harmful, rather it is quite helpful. She understands that states or international organizations of all kinds, if they hesitate to approve digital diplomacy is only because of the lack of preparedness and capacity to combat its risks. Therefore, digital diplomacy, as a product of the soft power of this new century should be combined with smart power, which means maximum utilization of the benefits of digitization and empowering protection policies against various threats arising from ICT, the internet, and social media. Moreover, she concludes that there is no escape from digitization which is, undeniable and unquestionable, a path with no return.

19. Available at: <https://bit.ly/38Vgzea>. Accessed on: Sept. 2021.

thinking on cyber diplomacy is a must.[20] For Goldman, that competition deals with two opposite models of world order – democracy and authoritarianism – and two opposite and competing visions of the digital space: information freedom and information control. She concludes that competition to shape the strategic environment gaining relative advantage must be continuous, persistent, and dynamic and it should be calibrated to remain below the level of armed conflict. Therefore, cyber diplomacy for strategic competition is essential to be improved.

For all the above, it is straightforward the crucial importance to include in this ST&I diplomacy discussion two essential subjects directly associated to cyber diplomacy: IoT and AI.

3.2 IoT and AI

According to Brian Burke (editor of Top Strategic Technology Trends for 2021), the trends for 2021 belong to three axes: i) *people centricity*: regardless of the pandemic changing how the people work and interact with organizations, they are still at the center of all business, therefore they need digitalized processes to function in the new environment.; ii) *location independence*: the pandemic from Sars-Cov-2 has changed where everyone (employees, customers, suppliers, organizations) physically exist; it is straightforward that this requires the availability of different technologies to give to the people ways to have activities independent of location to support this new version of business; and iii) *resilient delivery*: volatility always exists in the world independently of pandemics, recessions etc. and we have to be all the time ready to face that.

In the first axis, the main related innovations are internet of behaviors (IoB), total experience strategy and privacy-enhancing computing; in the second axis we find distributed clouds, anywhere operations and cybersecurity mesh; and in third axis we have intelligent composable business, AI engineering and hyperautomation.

All these innovations and their associated ST&I diplomacy are extremely important for the pos pandemic world. However, among them all, we will only

20. It is obvious that the time has come to up the diplomatic game for cyber competition however it cannot occur unless and until substantial assumptions about the evolution of norms, rules, and the applicability of a strategy of dissuasion to competition in cyberspace are set aside. According to Goldman, the competition is not only just about power but also about values. Autocratic regimes feared that digital-age capabilities would empower civil society and undermine their hold on power. For example, the so-called Arab Spring confirmed these fears and demonstrated the existential threat represented by information freedom. Of course, regimes in China and Russia oppose an open internet and protections against state interference with individual liberties. However, meanwhile, both Russia and China exploit open networks and platforms to erode democratic institutions in the West. Goldman considers that all these challenges will only grow as emerging digital technologies (for example sensors, technologies for information and communication, AI tools, quantum tools etc.) when they become new focal points for strategic competition. The more anticipatory we can get, the more we can inoculate our systems and prevent adversary aggression before it compromises the United States and other allied countries and partner networks.

approach IoT and AI, where IoT belongs to the second axis and AI belongs to the third axis.

Inside distributed cloud (second axis) there is IoT edge cloud which consists in the distribution of services that interact directly with edge devices. In general, distributed cloud provides public cloud options to different physical locations. In few words, a public cloud company maintains, operates, and evolves the services, and physically executes at the point of need.

On the other side, inside third axis AI engineering, projects often fail due to issues with maintainability, scalability, and governance. However, a robust AI engineering strategy will facilitate the performance, scalability, interpretability, and reliability of AI models while delivering the full value of AI investments. Without AI engineering, most organizations will fail to move AI projects beyond proofs of concept and prototypes to full-scale production. AI engineering stands on three core pillars: DataOps, ModelOps and DevOps. DevOps deals mainly with high-speed code changes, but AI projects experience dynamic changes in code, models, and data, and all must be improved. Organizations must apply DevOps principles across the data pipeline for DataOps and the machine learning model pipeline for MLOps to reap the benefits of AI engineering.

3.3 Quantum technology

On December 10th, 1945, just a simple switch was turned-on in Philadelphia, and from that on the age of modern computers began. That switch powered up for the first time the Electronic Numerical Integrator and Computer (ENIAC). ENIAC, in just a second, shifted the world from mechanical calculations to digital ones starting the age of the world's first electronic, digital, reprogrammable computer. It is the ancestral of every laptop, server, and smartphone used today. Immediately after that singular moment in human history, the arrival of such a powerful machine, the first screaming question was what to do with it and how it could change their lives. There appeared innumerous predictions but almost all of them have failed not because people were not smart or knowledgeable – it is just that predicting the future is hard. After all, while we may have missed out on moon bases and regular submarine trips, who could have predicted the internet or next-day delivery of just about anything? Often the most hyped predictions of the future are incorrect, only to be overtaken by initially more day-to-day, but ultimately radically transformative uses. Today, the world is experiencing a similar moment of information processing, however this time it is not from mechanical to digital, but from digital to quantum technologies. This is a *real* revolution, and it is a revolution in *quantum information science* where its basis is the quantum

mechanics (or quantum physics) theory.[21] As a consequence of this remarkable theory, in the last years were developed several equipment and procedures based on quantum phenomena like quantum computing, quantum sensors, quantum cryptography, quantum simulation, quantum metrology, quantum imaging etc. All of them use properties of quantum mechanics like quantum entanglement, quantum superposition and quantum tunnelling.[22] This represents the so-called Second Quantum Revolution.

By the end of 2017, Randolph Mank – a fellow of the *Canadian Global Affairs Institute* – published an article intitled *Quantum Diplomacy for a New Technological Age*.[23] In this article, the author suggests establishing parameters for developing quantum diplomacy to meet the challenges of this new era. Essentially, he proposes the eventual need for an international treaty to control both weaponization and proliferation of these new, powerful, and outstanding technologies.[24]

These new quantum information technologies will almost certainly have significant impacts on national security on every country reaching everything, from extremely secure communications to faster code breaking, for example to

21. Quantum mechanics is a subarea of the Physical Science developed in the early decades of the 20th century. Quantum technology is a new field of both physics and engineering, which relies on the principles of quantum mechanics. This is a fundamental theory that provides a description of the physical properties of nature at atomic or subatomic levels. On the contrary, *Classical Physics* describes many aspects of nature at macroscopic scale. However, it is not sufficient for describing most phenomena at atomic and subatomic scales. Quantum mechanics was arising gradually starting from theories explaining observations which could not be reconciled with classical physics, such as Compton effect, black-body radiation and the photoelectric effect. In 1900, Max Planck gave a solution to those open questions proposing the correspondence between both *energy* and *frequency* through the simple but famous equation $E = \hbar \times f$. It is amazing how a simple equation can change our vision of the Universe; that is the only reason we show it here in an article related to Human Sciences. These early attempts to understand microscopic phenomena, now known as the *old quantum theory or first quantum revolution*, led to the full development of quantum mechanics in the mid-1920s by scientist like Niels Bohr, Erwin Schrödinger, Werner Heisenberg, Max Born, among many other *holy monsters*. The modern theory is formulated in various particular and sophisticated mathematical formalisms. One of the key points of this theory is the existence of a wave function that provides information in the form of probability amplitudes and the way to measure the *observable* properties like particle's energy, momentum, among other physical properties

22. See, for example: Eisberg and Resnick (1985); Feynman, Leighton and Sands (1965); Merzbacher (1998).

23. Available at: <https://bit.ly/3m15xXr>. Accessed on: Sept. 2021.

24. Our dependence on IT systems is complete and absolute in all areas. In national defense this is certainly an extremely important factor. In that sense, what is the current state of the art in terms of high-performance computing? In June 2018, the International Business Machines Corporation (IBM) introduced the Summit, the world's fastest supercomputer built with AI and machine learning capabilities but without quantum computing capabilities or superconducting materials. This machine – considered to be the most powerful scientific tool ever created – was designed and built for the United States Department of Energy. It can perform 200 quadrillion mathematical operations (200 000 000 000 000 000 = $2x10^{17}$) per second and should assist in different types of research, ranging from medicine to advanced energies. Can the reader imagine what could be done with quantum computing? In the near future, when this technology will also incorporate room temperature superconducting materials into its architecture and processing? It's just unimaginable even for those in the business. We will achieve this in a matter of short time.

better detection of aircraft and submarines.[25] Moreover, it is also clear that today we are unlikely to be able to predict exactly what those impacts will be. However, for government leaders in national security who face significant stakes for getting things wrong, doing nothing is not an option. The question is: how can government leaders prepare for something they do not know about this quantum future? About this answer, Scott Buchholz and collaborators have published in 2020 a very interesting article (*The Realist's Guide to Quantum Technology and National Security*) that we strongly recommend to those outsiders of the Physics field of knowledge. There they say that "Pragmatic leaders can put in place the infrastructure to allow their organization to capitalize on whatever developments quantum may bring. However, to get more specific about what government leaders can do today to be ready for tomorrow's quantum world requires understanding what 'quantum' itself is" (Buchholz et al., 2020). Nothing truer than that.

4 SUMMARY AND CONCLUSIONS

All the remarkable areas we have briefly described here (AI, IoT, cyber diplomacy, and quantum technologies) represent the state-of-the-art in science and technology, and the correlated products, the state-of-the-art in innovation. Somebody in the past, said that *what does not challenge you,* does not transform you. Therefore, studying, understanding and working with quantum physics (or, more appropriately, quantum mechanics) is one of the greatest challenges in science. The resulting transformation in whoever achieves

25. Along with the undeniable and indisputable technological benefits of quantum mechanics, it also led – as an example – to the development of nuclear weapons a few decades later, which has had until present days a deep effect on global security and, of course, *diplomacy*. Given this repeated "from *promise* to *peril*" pattern it is surprising how little serious discussion has occurred around the diplomatic and security consequences of the latest wave of all new technologies and, among them, those derived from quantum mechanics. That is exactly the case of the new *quantum radar* developed very recently by China, most probably by Chines students from the best American universities and institutes of research who, coming back to China, work for their government as top scientist in a plethora of sensitive areas. These students, now top scientist in China, are product of the very well know ST&I Diplomacy American program. During President Trump's administration, the foreign policy changed, and the government started to restrict visas for Chinese students in strategic areas like science, technology, engineering, and mathematics for students coming from various Chinese universities. Maybe it is too late in many areas, but definitely it is too late for the United States Air Force and its Northrop Grumman B-2 Spirit bomber (among other models of invisible aircrafts). With its *flying wing* design that makes it almost *invisible* to radar, this war machine is truly a standout among military planes - and the world's most expensive, at over two billion American dollars per aircraft. When it was first introduced by the American Air Force, stealth technology represented a major shift in the conduct of military operations. Low radar observability – a more appropriate term for *stealth* – allowed American aircraft to safely penetrate heavily defended areas without being detected by enemy sensors. This optimum operational performance was demonstrated for the first time during the 1991 Gulf War. Today it is no longer a United States monopoly, since other countries like Russia and China have also deployed hardware with purported low-observability features. This technology remains to be an exclusive domain of advanced forces and provides a significant operational advantage. New experimental technologies, however, hold the potential to change the status quo. This is because the Northrop Grumman B-2 Spirit bombers will be no longer invisible. At least for Chinese military forces. A new kind of sensor tot in China, called *quantum radar*, holds the promise of detecting stealth platforms at a distance of at least 100 km. While this technology is still in its early stages and currently presents notable technical limitations, if successful it could play an important role in the next chapter in the everlasting dialectic between defense and offense in warfare. All this thanks to new quantum technologies and, maybe, thank to American universities for giving huge knowledge and intense training to Chinese students through different ST&I diplomacy programs.

this real intellectual feat is simply extraordinary and so the derived products. A complete new and amazing world. However, for the good or for the bad all these remarkable areas have both civilian and military applications. Particularly about AI, if the predictions of Raymond Kurzweil[26] are correct – and he has been remarkably precise so far – in the next 10-25 years, we will be approaching what he calls a technological *singularity* consisting of the merging of human and machine-based intelligence (Kurzweil, 1990). Out of any doubt, we are already traveling down this path where AI is found into more and more products every day. That is clearly a double-edged sword. In an interview with the British Broadcasting Corporation (BBC) in December 2014, and citing work done by the Future of Humanity Institute, Stephen Hawking warned that dismissing the dangers of advanced AI could be the "worst mistake in history". In that opportunity, he gave his first statement about AI technology saying that "if you try to create a thinking machine, then it will pose a threat to our existence". He also said that the result of an intelligence explosion could "outsmart financial markets, out-manipulate human leaders, and develop weapons we cannot even understand".[27]

On the other side, and while Stephen Hawking was warning against the existential dangers of fusing both AI and biology, Elon Musk has founded Neuralink,[28] a new startup aimed at achieving just this.[29] Can one be imaging the result of applying AI associated to quantum technologies? In several areas, including National Defense, not knowing or ignoring the technological applications of these possibilities is of a unique strategic gravity. We consider that the broad and correct politics of ST&I diplomacy are, maybe, the best way to guarantee the correct application of all these remarkable areas and their relationship with military technologies to keep the future mankind enough safe.

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26. Raymond Kurzweil is considered the father of the concept of exponential growing in all parameters of our civilization. He is an American futurist and inventor who has been involved in fields such as optical character recognition (OCR), text-to-speech synthesis, speech recognition technology, and electronic keyboard instruments. As a successful writer, he has written books on health, AI, transhumanism, the technological singularity, and futurism. He advocate for the futurist and transhumanist movements and gives public talks to share his optimistic outlook on life extension technologies and the future of nanotechnology, robotics, and biotechnology. Kurzweil received the 1999 National Medal of Technology and Innovation, the United States' highest honor in technology, from President Clinton in a White House ceremony. Available at: <https://en.wikipedia.org/wiki/Ray_Kurzweil>.

27. Available at: <https://bbc.in/3np3yx2>.

28. Available at: <https://neuralink.com>. Accessed on: Sept., 2021.

29. This startup will strive to develop a neural lace connecting the human brain and A.I. Musk's reasoning is that humans need to find a way to keep up with and control AI-capable machines. In Canada, the University of Toronto recently announced its advanced research and development in AI through the Vector Institute. Also, the Perimeter Institute as well as the Institute for Quantum Computing at the University of Waterloo are doing the same. The list of others around the world involved in the race to develop this technology is growing fast. Large corporations like Amazon, Google, Microsoft and IBM are already rapidly amassing most of recorded human knowledge in massive cloud data storage centers and moving ahead on AI as well. These repositories of what is known as Big Data, using the vehicle of the internet, will become the neural centers of the interconnected national and global systems, whose secure functioning will become vital to our future. They could also become our biggest problem, as Stephen Hawking said. In other words, our Achilles' heel.

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