Science diplomacy in an era of disruption

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Executive summary

We are in an era of disruption. The geopolitical context is increasingly adversarial, power is more widely distributed, and relationships among leading powers have become more competitive. The global scientific and technological landscape is being transformed and has made science and technology even more critical to national governments for economic growth and international competitiveness. Intertwined with this disruption are environmental challenges including climate change and biodiversity loss that continue to pose a significant threat to life on our planet. In this time of change and uncertainty, we need a framework on the practice of science diplomacy that recognises the world for what it is, that can be used as a tool for state and non-state actors, and that enables practitioners, from diplomats to industrial leaders, to address the challenges and even seize the opportunities of a disrupted world.

In 2010, the Royal Society and the American Association for the Advancement of Science (AAAS) published *New Frontiers in Science Diplomacy*, a report which outlined a framework for science diplomacy consisting of three dimensions: 'science in diplomacy', 'diplomacy for science', and 'science for diplomacy'. This report continues to be widely cited and discussed.

However, as the world becomes more divided and complex, and as the need for effective science diplomacy grows, it is necessary to ensure that the conceptual framework for science diplomacy facilitates its practical application. A science diplomacy framework should focus on how science and diplomacy engage. To do that, we propose a simplified framework that is constructed around the two dimensions of interaction between science and diplomacy.

Two dimension science diplomacy framework

Science impacting diplomacy
The different ways that science interacts with diplomatic objectives.

Diplomacy impacting science
The ways that diplomacy interacts and engages with the scientific enterprise.

These two dimensions of science diplomacy do not mean that there are only two ways for science and diplomacy to engage with each other. Instead, they provide a framework that incorporates the multiple ways for science to interact with diplomacy and for diplomacy to interact with science. AAAS and the Royal Society intend that, in simplifying the framework, we are creating a more flexible one that can adapt to the pressures of the present and the future. In developing this new framework three key points also emerged in how science diplomacy is practiced.

Science diplomacy is an important tool for the conduct of international relations

Scientists aim to obtain and hopefully apply new knowledge about the world, while the practice of diplomacy will always involve the pursuit of national and/or institutional interests. Many practical examples demonstrate how these worlds, when their interests are aligned, can work together to great effect, from climate assessments to the construction and operation of large infrastructure. The 2010 report was framed mostly around positive interactions such as these, which can lead to the notion that science diplomacy is always positive and/or is a tool in the interest of the global good. However, this is not always the case. Rather, science diplomacy is a tool that is used to achieve a nation or organisation's diplomatic objectives, and those objectives can be perceived as positive or negative.

Science diplomacy is increasingly used by non-state actors

Those using science diplomacy as a tool to achieve their national and international objectives are typically, but not exclusively, diplomats representing their national governments. In recent years, there has been an increase in non-state actors, particularly global technology companies, using science diplomacy to conduct their own equivalent of 'statecraft' in support of their company's objectives, which may be distinct from those of any national government.

Disruption demands science diplomacy

Societies are being rapidly upended by an array of extraordinary science, engineering, and technological advances. Advances in artificial intelligence (AI) are evolving faster than regulatory and governance regimes can keep pace. A small number of huge multinational companies that develop, manufacture and supply these highly advanced technologies are increasingly becoming diplomatic actors in their own right.

The open system of international scientific collaboration is being exploited to strengthen some national military capabilities, leading to heightened concerns about research security. Previously ungoverned spaces – for example, the deep oceans, the poles, the moon, and inner and outer space – which were once considered largely as the domain of scientists due to their inaccessibility, are now much more accessible and thus subject to political contestation.

Further, there has been limited progress on preventing, mitigating, and adapting to global challenges, including climate change and biodiversity loss, as well as continuing high levels of global poverty. More than eight billion people now inhabit the Earth, and the greatest threats facing present and future generations remain largely unsolved.

We are living in a pivotal moment, witnessing the convergence of a number of developments that pose opportunities and challenges alike. To face these challenges and uncertainties, the tool of science diplomacy will play a more important role for both state and non-state actors.

Consultations: overarching themes

The development of this report was informed by a wide variety of stakeholders who provided input at roundtables, meetings and international events, and through a special issue of *Science & Diplomacy* titled *Science Diplomacy – 15 Years On*[1]. This consultation lasted over a year, and AAAS and the Royal Society would like to thank all those who participated in these events and provided invaluable perspectives. The key messages from those consultations which are reflected in this report, are the following.

- **Science is ever more central to foreign policy, and vice versa.** Science has been increasingly integrated into many sectors across society (including defence, trade, law, and intelligence), which makes the interaction between science and diplomacy more important than ever. National governments and multilateral organisations, such as the United Nations (UN), the G7 and the G20 are increasingly incorporating science into their advisory mechanisms.
- **Scientific and diplomatic interests may not coincide.** Scientists seek knowledge, while diplomats pursue the interest of their nation (or other entity). There are many examples of scientific and diplomatic interests conflicting. There are many examples of conflicting scientific and diplomatic interests. For instance, treaties governing the global commons that theoretically safeguard them for scientific research are increasingly coming into conflict with sovereign national interests.

- **Scientific values once thought universal are now being re-examined.** The notion that there are universal scientific values, shared by all countries, has been called into question, which has implications for the potential practices of international scientific collaboration and science diplomacy.

- **There is a need for awareness of national security risks in scientific collaborations.** Scientists must carefully scrutinise the intentions of potential research partners and their networks, while policy makers, who are increasingly concerned with research security, should be as open as possible about the threats they seek to avoid.

- **Clarity and transparency are needed regarding the roles and responsibilities of practitioners of science diplomacy.** Scientists and diplomats operating in the sphere where their two fields meet should be clear on their respective roles and responsibilities for the benefit of their working relationship, as well as for building public trust.

- **Science and science advice face increased scrutiny.** Trust in science and the use of evidence in policymaking is under renewed attack across the world. Science advisers must ensure that their advice to policymakers is driven by fair and robust assessments of the best available evidence, and accompanied by clarity about what is not known and what is uncertain. Science diplomacy is distinct from science advice but often incorporates it.

- **Non-state actors play increasingly important roles.** Major companies, 'tech titans', and philanthropic organisations have growing scientific, economic, and political influence, in some cases as much as individual nations. These non-state actors engage increasingly in science diplomacy and the use of 'soft power' to promote their own interests.

- **There is a need for inclusive international scientific collaboration.** Scientists from emerging scientific countries and/or early career researchers are advocating for more equitable partnerships in global research collaborations. They and others like them are critical in ensuring there is a wider diversity of voices in science diplomacy, as well as offering important challenges in terms of how best to recognise and reconcile different views and values.

Introduction

In 2010, the American Association for the Advancement of Science (AAAS) and the Royal Society published a landmark report, *New Frontiers in Science Diplomacy*, following a joint high-level international meeting at the Royal Society in June 2009[2]. Neither of these organisations nor that meeting invented the term, but rather sought to clarify the roles of science diplomacy, which has been practised for centuries. Regardless, the 2010 report did popularise the term, which was then adopted around the world at extraordinary speed. In 2012, the European Commission first used the term in an official communication[3].

References to science diplomacy can now be found in high-profile conferences[4], university courses[5], the speeches of ministers and senior diplomats[6], and even some national science diplomacy strategies[7]. The conceptual framework of science diplomacy, as outlined in the original report, developed into a widely understood reference point.

But the world changed profoundly between 2010 and 2025, and so must the practices of science diplomacy. In the past 15 years, the original report has appeared ever more tied to the age in which it was written, and an increasing number of critiques have been advanced.

These critiques have, among other things, variously accused advocates of the concept of being naive[8]; of creating a buzzword[9]; of imposing a product of the Global North on the Global South[10]; and even of being a front to cover less savoury national interests[11]. It is time to re-examine and update the 2010 report's findings to ensure that science diplomacy is a tool robust enough to interact with the challenges of the world today.

That is the aim of this report. It draws on a year of evidence-gathering, beginning with a roundtable in London, UK in November 2023, and continuing through sessions at the AAAS Annual Meeting in Denver, US, in February 2024; the International Network of Government Science Advice (INGSA) conference in Kigali, Rwanda in May 2024; the Science, Technology and Society (STS) Forum in Kyoto, Japan in October 2024; and the World Science Forum in Budapest, Hungary in November 2024. In addition to these high-level scientific meetings, a joint special issue of *Science & Diplomacy* was published, with a wide range of perspectives on science diplomacy from Cuba, Israel and Palestine, China, Ukraine, South America, South Africa, and more, including new critiques and refinements of the concept[12]. Together, these initiatives convened a wide range of experts and stakeholders from around the world in a variety of sectors and drew on a number of different approaches to bring their experience and expertise to the task. We would like to thank all those who participated.

AAAS and the Royal Society hope this report will be useful in reinvigorating the concept of science diplomacy for the mid-to-late 2020s and beyond but recognise that it neither will nor should be the final word on the subject. One of the key successes of the original concept is how it has been adapted across different countries, regions, institutions, and cultures. For example, science diplomacy practiced in South America has its unique characteristics[13] as does science diplomacy practiced in the Pacific[14].

It is time to re-examine and update the 2010 report's findings to ensure that science diplomacy is a tool robust enough to interact with the challenges of the world today.

That said, the concept of science diplomacy has increasingly become subject to 'mission creep', in some cases referring to almost any kind of international scientific collaboration. While this report is not seeking to gatekeep what constitutes science diplomacy and who can practice it, it argues that there is a need to reclaim the term to some extent from those who apply it too liberally. There are risks in overselling the concept and in blurring the distinctions between scientists and diplomats.

Briefly, it is crucial to clarify a couple of points on the respective meanings of science and diplomacy. First, references to 'science' in the term 'science diplomacy' encompass the gamut of scientific disciplines. This refers not only to the natural sciences, but also to the fields of engineering, technology, the social sciences, and others. It can also refer to any stage of the scientific process, from research and development to scientific training and education. When we refer to 'science diplomacy' in this report, it implicitly includes all scientific fields. Second, science diplomacy is an umbrella term which includes sub-fields such as climate or technology diplomacy.

Diplomacy is the activities of a nation (or an organisation) to advance its interests outside its boundaries or borders. It is important to distinguish between foreign policy and diplomacy, terms which are used frequently in this and other relevant reports. Foreign policy represents the political choices of governments in pursuit of perceived national interests. Diplomacy is the principal means by which foreign policy is put into practice.

But it is not the only means of pursuing foreign policy. It is one aspect of statecraft, the practice of which has been defined as "the art of conducting public affairs"[15]. Alongside diplomacy, other tools of statecraft in international relations include the use of 'hard power', a euphemism for military threats or actions, and 'soft power', the use of cultural or economic levers to influence the behaviour of foreign states.

Diplomacy is a practical activity undertaken in an imperfect world. Because diplomacy serves national interests (or the interests of its practitioner and those it represents)[16], this creates the potential for tensions between diplomatic goals and the pursuit of scientific progress.

It is also important to recognise that diplomacy is conducted not exclusively by diplomats, but by many parts of government and (in soft power diplomacy) nongovernment actors, such as those involved in industry, civil society, and academia.

Science diplomacy – a summary

Fundamentally, science diplomacy is about the interactions between science and international relations and how these can combine to most effectively achieve shared objectives. The role of a scientist is to generate new knowledge about the world, and sometimes to apply this knowledge for the benefit of humanity. A diplomat's purpose is to represent and serve the interests of their country, company, or multilateral institution. The arena of science diplomacy is where scientists and diplomats interact.

2010 report – *Three dimensions of science diplomacy*

The 2010 report laid out a framework for science diplomacy with three dimensions: science in diplomacy, diplomacy for science, and science for diplomacy. Additionally, the report provided case studies of science diplomacy, assessing how science could be used to strengthen relations with the Islamic world and the governance of international spaces, in particular the Antarctic Treaty.

The document described science in diplomacy as informing foreign policy objectives with scientific advice. This dimension of science diplomacy focused on the role of individual expert advisers or scientific organisations, for example national academies, in informing policymaking, and on other means of providing scientific advice to global policymakers, such as through rigorous evidence syntheses. Examples of the latter include the Intergovernmental Panel on Climate Change (IPCC), which provides scientific advice on the current state of climate change and its environmental and socioeconomic consequences.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) performs a similar role pertaining to biodiversity. These are both excellent examples of what policy makers need most of all from researchers: high-quality syntheses of what is known and what is uncertain or unknown about key topics.

The diplomacy for science dimension was framed as the facilitation of international cooperation both at the 'top-down' strategic level, and at the 'bottom-up' level of collaborations between individual scientists. 'Top-down' examples include the International Thermonuclear Experimental Reactor (ITER), a large-scale international scientific infrastructure which aims to demonstrate the scientific and technical viability of a fusion energy source, and the Square Kilometre Array (SKA), an intergovernmental international radio telescope project being built in Australia and South Africa, headquartered in the UK, with a consortium of member countries from around the world. Others include bilateral summits between nations to strengthen scientific cooperation, for example through introducing funding schemes and/or facilitating supportive environments for cross-border collaborations. It is initiatives such as these that enable individual scientists to initiate bottom-up collaborations with their counterparts from around the world.

These include the role of science diplomacy when science is one of the causes of competition or conflict rather than a tool for progress and peace.

The third dimension, science for diplomacy, is the use of scientific cooperation to improve international relations between countries. This dimension includes science cooperation agreements and scientific facilities established with the objective of improving relations between countries; an example is the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), housed in Jordan, the only country that maintains diplomatic relations with all the other founding members (which include Israel and Iran, among others). This dimension also includes 'track two' diplomatic efforts, which are aimed at influencing formal diplomacy ('track one') but include nongovernmental participants and informal dialogue. Science has played a significant role in these dialogues in the past and is well placed to do so now at a time of international tension[17].

The need to update the framework

Since the publication of the 2010 report, these three dimensions – like the term 'science diplomacy' itself – have gained widespread recognition. However, they have also generated confusion at times, including through the evidence-gathering for this report. For one, the similarity of the wording means that they can be easily mixed up. Further, the differences between the three may be difficult to discern in practice, with some activities falling into more than one category. This has led some to suggest that science diplomacy should be reframed into new categories defined by actions – actions that directly advance national needs, actions that address cross-border interests, and actions that are designed to meet global needs and challenges[18].

Science diplomacy has even spawned its own sub-fields, such as technology diplomacy and climate diplomacy, which have been the subject of various initiatives[19]. Others have taken an even broader lens, developing the nascent concept of 'knowledge diplomacy', which goes beyond science and research to include educational, cultural, and innovation diplomacy[20].

There are also concerns about issues that did not feature in the 2010 report. These include the role of science diplomacy when science is one of the causes of competition or conflict rather than a tool for progress and peace. A good example is the growing US-China competition, in part fuelled by rivalry over sensitive technologies such as AI and semiconductors, which were notably excluded from a recently renewed S&T agreement[21].

Further, while much of the literature on science diplomacy references cooperation during the Cold War, these precedents are less relevant in the context of the 'hot wars' raging today in Ukraine, the Middle East, and Sudan[22]. Some authors for Science & Diplomacy's special issue proposed a fourth dimension to the original framework which would encompass these conflict and security concerns[23,24].

Additionally, the rise of a small number of multinational corporations of an economic scale greater than that of many nation-states, and even of extremely wealthy individuals engaging in science diplomacy, was not considered in the 2010 report.

Acknowledging both the usefulness of the 2010 framework and the validity of critiques of it, this report considers what the evolving geopolitical context means for science diplomacy now and in the future and reassesses how science and diplomacy interact and work together. This work is not meant to discredit the original report – and clearly benefits from hindsight not available to the authors of that report. Rather, it recognises that definitions and debates over theory, while useful, can sometimes distract from the ultimate goal: providing guidance for practitioners based on real-world examples. The practice of science diplomacy is what really matters.

What science diplomacy is not

The 2010 report and other literature on science diplomacy have made useful observations on what science diplomacy is; it is also worth discussing what science diplomacy is not.

As with any term, 'science diplomacy' can obscure more than it clarifies if carelessly applied. For example, there is an increasing tendency to call almost any kind of international science collaboration, even simply having an international meeting, 'science diplomacy'. This may seem harmless, but it can obscure the very real differences between what scientists and diplomats do and the years of training required to build up the necessary expertise to perform either role. It is unlikely that a diplomatic endeavour with no scientific content would be labelled in this way, and so the reverse should also apply. Too broad a definition ignores the difference in motivations, or confuses the roles of different actors. It drains 'science diplomacy' of any real meaning. Put another way, if science diplomacy is everything, it is nothing.

Moving to a new framework

A central critique of the 2010 report is that it was overly optimistic about the potential of science diplomacy to solve global challenges, and assumed a commitment to multilateralism and global solidarity that seems increasingly unrealistic. Indeed, as the next section describes, most of these challenges, where science is critical to international policymaking, have only become greater. Meanwhile, new and potentially destabilising forces have emerged, including the misuse of advanced information technologies such as AI, and a global resurgence of authoritarianism affecting nearly all continents. It is worth reiterating that science diplomacy is fundamentally a tool that is used by different actors in different ways depending on their fundamental interests. Science diplomacy may be used to promote cooperation and the peaceful sharing of knowledge. But it can also facilitate rivalry and competition.

The need to move the framework from theoretical to practical is reflected in our new, streamlined framework (outlined in detail in Section 4). The revised framework focuses on the interaction between the two entities at play: the fields of science and diplomacy. It simplifies the framework from three to two dimensions: science impacting diplomacy and diplomacy impacting science.

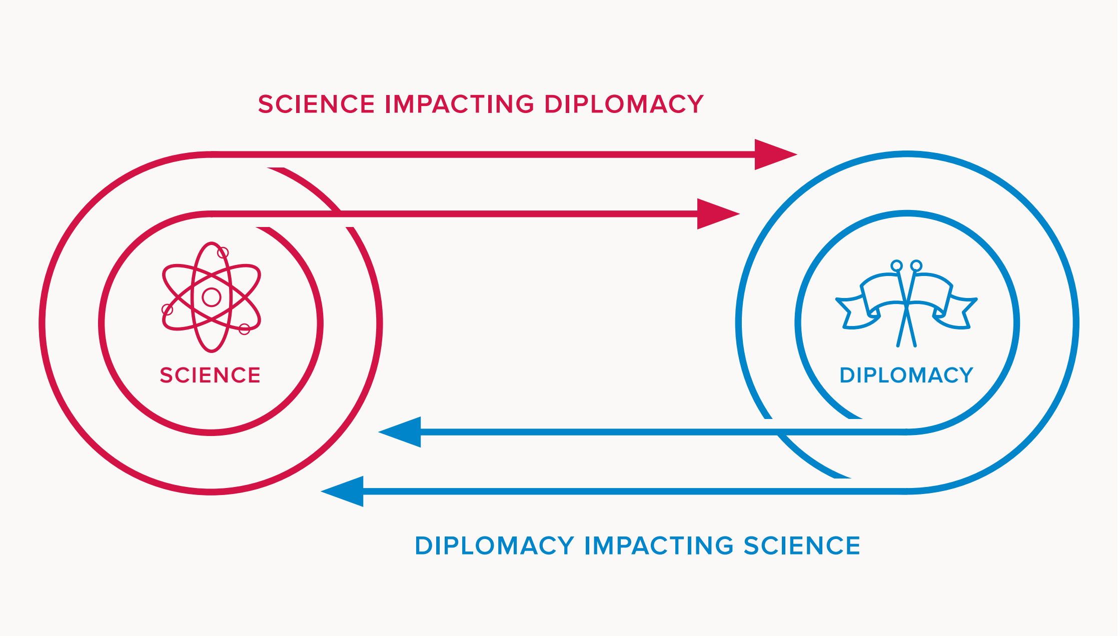
If science diplomacy is everything, it is nothing.

Science diplomacy is fundamentally a tool.

This two-dimensional framework does not suggest that there are only two ways for science and diplomacy to engage, but rather provides the flexibility to describe the multiple ways they interact. Further, this revised framework provides greater adaptability to encompass current and future scientific and technological changes, as well as the evolving geopolitical landscape they operate in.

In reviewing the framework, we recognise that this report may seem darker, more realistic, and hard-edged, than its predecessor. This reflects the realities of the past 15 years. At the same time, it also makes an argument that the value of science and diplomacy working together is now more important than ever. Both the 2010 report and this one include case studies from around the world that show the many productive ways science diplomacy is being practised. A key theme is the role that science diplomacy can play in building trust, at a time where global trust in institutions and between nations is in many cases declining.

FIGURE 1



An increasingly fragmented and dangerous world

2010 was characterised by much greater geopolitical stability and multilateral cooperation than now. The emergence of social media such as Facebook and Twitter, initially adopted mostly by younger audiences, was met with optimism. This was partly due to its perceived role in contributing to the so-called 'Arab Spring' which began at the end of that year, as well as the 2008 US election and the subsequent prospect of improving US relations with Russia and the Islamic world. Earlier that decade, multiple 'colour revolutions' in support of liberal democracy had been breaking out in various former Soviet states[25]. All these developments were thought in 2010 to herald a new era of widespread democracy, openness, and collaboration. The science diplomacy report captured the mood of the times.

Fifteen years on, the world has changed in fundamental ways, all of which have had impacts on the worlds of science and diplomacy and have major implications for how the concept and practice of science diplomacy should be redefined. Simply put, the range and scale of the challenges facing humanity have grown considerably since 2010.

Global challenges

Environmental challenges such as climate change, pollution, biodiversity loss, and infectious diseases have overall worsened. More than eight billion people are indelibly impacting the planet and the many other species with which we share it. Carbon emissions from burning fossil fuels are driving climate change and ocean acidification. Chemical waste is poisoning ecosystems on land and in the air and water. Biodiversity is diminishing, as the worsening quality of many environments and rapid changes to others are causing the extinction of vulnerable species across the planet.

As the COVID-19 pandemic demonstrated, growing human populations, living closely with other species, are becoming more vulnerable to emerging infectious diseases. The widespread use of air travel means these can spread across the world at extraordinary speed. Global warming is enabling the spread of insect vector-borne infections, hitherto limited to tropical regions. Widespread antibiotic resistance is allowing 'traditional' infections to re-emerge with deadly potential. All the while, noncommunicable diseases, such as cancer, diabetes, and ageing-related neurodegenerative diseases, are also putting increasing pressure on societies around the globe. There is a greater need than ever for scientists to understand these rapidly unfolding and worsening problems through scientific research, and to help identify potential solutions, including potential new policy options for international policymakers to consider.

Indeed, the pandemic demonstrated well the potential of science diplomacy in a crisis – notably, in the internationally collaborative efforts to understand the virus, track its spread, and develop a vaccine[26]. This period was characterised by data sharing and mutual learning by scientific advisers and governments around the world. It also underscored the limits of cooperation in a global pandemic emergency, as national governments competed over the supplies of protective equipment, and the equitable distribution of vaccines proved difficult, despite initiatives such as the World Health Organization's COVID-19 Vaccines Global Access (COVAX) programme. Indeed, the experience of some lower- and middle-income countries in being unable to access key technologies and products undermined trust, negatively impacted international relations, and has led to calls for the reform of intellectual property (IP) protection regimes and for greater representation in setting global norms.

The world also faces a growing number of demographic challenges. In wealthier countries, endogenous population growth has slowed or ceased. In many of these countries, as a result of increased average human longevity associated with improvements in public health, the population of young people is declining faster than the growth in the population of older people.. This raises important questions about who will provide and pay for the health care, retirement needs, and pensions of older people.

In stark contrast, in many lower- and middle-income countries facing persistent poverty, inequality, and environmental challenges, population growth continues apace. In addition to being one of our world's greatest challenges, this also involves a demographic element. When younger people face poverty, food shortages, political unrest, and greater competition for jobs, those who have the ability to do so may migrate to countries which appear to have better economic prospects and a safer environment, but where they are often met with suspicion, resistance, and hostility. When restrictions on migration are implemented in response to political demand, this can sometimes adversely impact science, as the mobility of scientific talent may then also be impacted (whether intentionally or not)[27].

The fourth industrial revolution

The global technological landscape is being transformed and disrupted by the so-called fourth industrial revolution, for example with near-daily advances in AI, information technology, quantum technologies, robotics, autonomous systems, space technologies, genomics, and genetic engineering. These technologies have impacted: international scientific collaboration, which can take place more easily with advanced communication technologies; the intelligence community, which uses social media to monitor people's activities or influence political opinion; and diplomacy itself, by enabling government officials to work directly with their international counterparts and sometimes to bypass or 'disintermediate' the diplomats who previously served as their go-betweens.

These technological developments and their rapid exploitation have made science even more critical in the increasingly urgent drive by national governments to deliver economic growth and international competitiveness. This is reflected in calls for R&D investment, more interventionist industrial and trade strategies, and shifting relationships amongst governments, regulators, and wealthy corporate actors. Examples include the privatisation of space exploration and the role of vaccine producers in influencing the extent of global access to life-saving vaccines. In setting foreign policy priorities relating to economic growth, critical and emerging technologies, and resilient access to scarce resources, governments need to cultivate close relations with both the research community and the commercial deployers of science in the economy.

This raises an important sidequestion about the level and affordability of scientific skills in the public sector. Science has also assumed a critical role in the emergence of new threats to security, including cyber threats to critical infrastructure, growing misinformation[28], and increasing concern over how international scientific collaboration may be exploited for military purposes or illicit technology transfer.

This had led to new and rapidly emerging technologies being the subject of increased global competition, both economic and military. The pace of this technological development is so rapid that regulators and analysts struggle to keep up, and global inequalities are exacerbated. This widened range of stakeholders and the ease of technological transfer (both lawful and unlawful) also limit the ability of states to protect sovereign advantage. Finally, there has been extraordinary growth by a small number of massive global technology companies whose economic strength and international influence exceed those of many nation-states. Their scale and global footprint make them 'supranational' entities.

Geopolitics

The geopolitical context of today is increasingly adversarial, fragmented, and contested. Power is more widely distributed, and today's influential states have less in common with each other, both in general terms and in terms of shared values. A key tension at the heart of this is the increasingly antagonistic relationship between the US and China, resulting from the growth of China's political and economic power and profound shifts in US politics.

The world today is also more dangerous, with major wars in Ukraine, the Middle East, and Sudan. These conflicts and others have further polarised global politics and adversely impacted regional and global science. The fallout from these wars has severely impacted academia and research along with all other aspects of life in these regions[29]. The other area where change has been most evident is in relationships with Russia, after Western institutions halted scientific partnerships with the country in response to its invasion of Ukraine in February 2022[30].

Diminished political will to collaborate has also weakened multilateral institutions and initiatives promoting collective endeavours on issues such as climate, health, and trade. In many countries this is a result of an increasingly polarised and partisan domestic political climate, fuelled partly by social media, which has seen scientists forced to fight a rearguard action against misinformation[31].

International collaboration is therefore becoming more common among like-minded countries or politically aligned groups, such as the Organisation for Economic Co-operation and Development (OECD), the G7, BRICS, the European Union (sometimes including some of its neighbours), and the 'Five Eyes'. However, this is not just a case of competition between like-minded blocs, some of which may have different value systems. There is also the potential for further fragmentation within these groups. Recent political developments in the US, UK, and EU have highlighted the potential for greater policy divergence and competition, even between ostensible allies.

The geopolitical context of today is increasingly adversarial, fragmented, and contested.

Indeed, international scientific collaboration itself, once seen as an unalloyed good, is now coming under greater scrutiny to ensure that its benefits are spread evenly. Researchers in the Global South are increasingly calling for fairer recognition of their contributions to global science in the form of more equitable partnerships[32] and fairer research collaborations[33]. Meanwhile policymakers in the Global North are increasingly focused on threats to their research from collaborators who transfer technology from them for free, or who use it for purposes that are hostile to their interests.

While there are serious economic and national security implications in the case of the theft or misuse of intellectual property, today's more multipolar world can also provide opportunities. The more even distribution of power has led to a much greater variety of scientific nations from all areas of the world, in particular the Global South, and to an increasing global distribution of high-quality scientific research.

All these environmental, demographic, technological, and geopolitical changes are interacting in unexpected ways. Sometimes these developments have positive impacts, not least in how they have enabled a greater number and range of voices, countries, and institutions to be represented in global science and science diplomacy. Other developments are more challenging, leading to greater global unrest, rising nationalism and populism, and potentially a more difficult environment for scientists who find themselves caught in the crosscurrents of increasingly polarised politics.

This analysis illustrates that the more optimistic age in which the 2010 science diplomacy report was published is over. This means that the practice of science diplomacy is more important than ever. A more complex, fragile, and contested global landscape brings with it a growing variety and intensity of problems that require robust scientific evidence to inform the diplomacy needed to address them. To do so, the practice of science diplomacy must evolve accordingly.

What this changing world means for science diplomacy

Although awareness and understanding of this changed geopolitical context may vary among scientists, they are not exempt from its implications. In fact, a common theme across the consultations undertaken for this report is that science does not and cannot operate outside geopolitics. Perhaps the most immediate example of this is how the combination of rapid technological development and contested geopolitics has resulted in a much greater focus on the national security risks associated with international scientific collaboration.

Research security

Science has always been a global endeavour, and in most cases, academic research is open and freely shared with the global community. The 2010 report went so far as to state that 'scientific values of rationality, transparency, and universality are the same the world over'. But different countries, including leading S&T nations, may not always share the same research values or be aligned philosophically. This has increased the risks associated with international scientific collaboration and partnerships. In the absence of open dialogue, these divides will only deepen.

The risks of 'dual use' (ie research that can be used for both civilian and military applications) were only briefly acknowledged in the 2010 report, and largely framed as barriers to collaboration that needed to be overcome as opposed to barriers that had to be recognised and respected. The ability to assess the potential for military application of research is particularly complicated by states that purposefully fuse and eliminate barriers between civilian and military research[34].

Along with the potential for scientific discoveries to be used for military purposes, another aspect of research security is the protection of IP against potential theft or misuse. Such theft can involve sensitive data, copyrights, patents, trademarks, or trade secrets, as well as the casual sharing of informal know-how. This stretches beyond leading scientific nations, and can also be seen in the theft or miscrediting of Indigenous knowledge[35], as well as the lack of acknowledgement towards countries with less prominent scientific ecosystems. Today, with new technologies, it is easy in principle to share vast amounts of data[36]. However, differences in value systems which assign varying levels of priority to considerations such as individual privacy, national security, and IP among others, can in practice result in barriers to data sharing and open science.

Governments have called on researchers and their funders to protect important research ecosystems, safeguard them against potential national or economic security risks, and protect them against the interference of foreign governments[37,38,39]. Research security has become an active area of discussion and activity at the multilateral level as well. The G7 established a working group on the topic that has released a set of common values and principles on research security and research integrity[40], and the OECD has published a report and established a portal to various resources on the topic[41]. The trade-off between safeguarding the security of scientific research and keeping research collaboration as open as possible has become one of the most critical questions in contemporary research policy.

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These competing agendas underscore the need for clarity and transparency. Those charged with protecting research security should make it clear when that protection is being deployed against 'dual use', when it is aimed at preventing the theft of IP, and when other concerns such as privacy or national security, are at play. They will be doing so in support of their national interests and values, which vary between nations.

Research security represents a new and difficult area of science diplomacy. Controls for national security purposes should be balanced with the value of international collaboration, which often increases both the quality and impact of research, as well as building positive relationships between countries[42]. What effect research security efforts have on the processes and outcomes of science diplomacy is not yet clear, although research on this topic is increasing[43].

Ungoverned spaces and international scientific infrastructure

Spaces that cross or exist beyond national borders – including the polar regions, outer space, and the deep oceans – are often referred to as 'global commons'. These spaces have in common harsh environments and inaccessibility to long-term human habitation. They are scientifically fascinating and important, teaching researchers much about our own planet and the universe, of which we are an infinitesimal part.

Given such global importance, these spaces have also been the subject of diplomatic negotiation. During the Cold War and immediately afterwards, several of these spaces became governed by intergovernmental agreements, which were focused largely on peaceful uses, making them the domains of scientists. The International Space Station (ISS) was built by the United States and the Soviet Union (and its successor states) along with partners in Europe, Japan, and Canada, and is governed by the 1988 Space Station Intergovernmental Agreement. Similarly, the Arctic Council was founded in 1996 as a high-level intergovernmental forum to enhance cooperation, coordination, and interaction among the Arctic States – see Case Study 1[44].

However, recent geopolitical developments, especially the 2022 full-scale invasion of Ukraine by Russia, has left the future of these international collaborations in question. Russia has announced it will leave the ISS and focus on launching a new space station of its own – not unlike the Tiangong space station which China operates independently. Just weeks after the invasion of Ukraine, the seven non-Russian Arctic Council members agreed to boycott future meetings and halted the work of the Council. Similar efforts have taken place elsewhere. For example, the European Organization for Nuclear Research (CERN) ended its cooperation agreement with Russia and terminated the participation of Russian scientists in its programs[45].

Any assumption that ungoverned spaces or international scientific facilities could somehow rise above geopolitics has been shown to be false. A renewed consideration of the interaction between science and diplomacy is needed to navigate these intergovernmental agreements through times of conflict.

Additionally, the increased accessibility of these ungoverned areas, underpinned by the development of new technologies and the widespread adoption of others, has paved the way for industrial and geopolitical competition. Accessibility has also created new problems in its wake, such as the harm caused to seabed life by the dredging of the deep oceans, the exacerbation of light pollution, and the proliferation of space debris caused by increasing numbers of satellites, the majority of which are launched by the private sector. What role the focus on potential commercial and sovereign gain will play in this changing geopolitical environment, especially in cases where relevant companies are headquartered in countries that are in active conflict, remains to be seen (see Case Study 2).

Science advice and its politicisation

Science advice to policymakers is not new. The US appointed its first science advisor during World War II, the role of Chief Scientific Advisor to the UK government was formalised in 1963; and more recently, countries including Australia, Canada, Czechia, India, Ireland, Malaysia, and New Zealand have established chief scientific advisers. Along with science advisers at the top of government, there are an increasing number of science advisers within other government departments. Additional countries have created or expanded the role of science counsellors and attachés, and/or have created new science-related mechanisms and roles at their embassies[46].

Scientific advisory bodies or systems have been developed at the multilateral level as well. The UN Secretary General has a Scientific Advisory Board, and many nongovernment organisations – such as the InterAcademy Partnership (IAP), The World Academy of Sciences (TWAS), the International Science Council (ISC), and the International Network for Governmental Science Advice (INGSA) – also play active roles, to varying degrees, in providing scientific advice to governments and other influential bodies. Additionally, many national academies of science around the world provide rigorous science advice, work multilaterally at global and regional levels, and feed into intergovernmental groupings to provide scientific advice – for example, to G7, G20, and BRICS meetings.

Any assumption that ungoverned spaces or international scientific facilities could somehow rise above geopolitics has been shown to be false.

The politicisation of science advice became a major challenge during the early days of the pandemic, in response to recommendations for social distancing measures and other emergency policies. The pandemic provided examples of what happens when science is developed in real time. Scientists and medical professionals publicly discussed evidence and treatments, which may have exacerbated a perception by the general public that scientists were in fundamental disagreement; in fact, evidence was still accruing as part of the normal scientific process. For a public – and policymakers – that urgently needed to make swift decisions in response to the pandemic, this led to doubt and distrust.

The experience of the pandemic showed that the scientific community needs to do a better job conveying to the general public the scientific process – namely, that science is always a work in progress[47]. Additionally, the pandemic illustrated the need for increased clarification of the different roles and responsibilities of scientific advisers and government policymakers, because in some cases, members of the public perceived that some scientists had crossed the line into 'issue advocates', given how restrictive some of their recommended measures against the virus were.

A high level of transparency is even more critical now with the rise of populism and authoritarianism, which raises concerns that some governments may use or abuse science and science advisers to pursue their political agendas, further eroding trust in science[48,49].

Science as a diplomatic tool

There are many historical examples of science being used to achieve diplomatic objectives. Indeed, international engagement and collaboration in science can sometimes be the sole route of communication and engagement between nations during politically contentious times. Establishing scientific cooperation programmes or S&T agreements is often the first thing countries undertake when trying to improve or restart their official relations. The US-China Science and Technology Agreement was the first agreement signed after the United States recognised the People's Republic of China in 1979, while the EU-South Africa Science and Technology Cooperation Agreement was the first agreement signed between the two entities following the end of apartheid in South Africa[50].

More broadly, international scientific cooperation can be an effective expression of soft power as part of a nation's larger diplomatic efforts. For example, S&T cooperation has been a significant component of China's Belt and Road Initiative through developing international technology transfer centres, science exchange programs, and capacity for S&T in participating countries.

Establishing scientific facilities can also be part of multilateral diplomatic efforts. For example, the International Institute for Applied System Analysis (IIASA) was set up during the Cold War to bring together US and Soviet researchers to build partnerships and confront global problems, while SESAME was established as a bridge across the Middle East and includes Israeli, Palestinian, and Iranian researchers.

The use of diplomatic tools to foster scientific cooperation is well known. However, the ways in which statecraft, including sanctions, can impede scientific cooperation is less well understood. Trade sanctions can impact what type of scientific equipment is available; financial sanctions can restrict the movement of funds, including between research institutions; and military and weapons sanctions can impact scientists working not only on defence, but also on projects for civilian use depending on what scientific equipment or projects are considered 'dual use'. The US embargo on trade with Cuba, which started in 1958, has expanded and become one of the most enduring trade embargoes in modern history, with major impacts on scientific collaboration between the countries. Sanctions against the Democratic People's Republic of Korea (DPRK) since the 1950s, which have been expanded and have escalated to multinational sanctions through the UN Security Council, affect international scientific collaboration as well[51].

The imposition of such sanctions has increased in recent years which illustrates growing geopolitical tensions[52] and in turn has led to a wider range of measures intended to police technology flows in key sectors, including semiconductor chips, AI, quantum computing, genomic science, pharmaceuticals, and nuclear technology. A strong scientific understanding of these technologies, the risks they pose, and the opportunities associated with them is therefore required by policymakers in order to most effectively assess how national and international interests should be balanced.

Industry

Since 2010, non-state actors have increasingly shaped science diplomacy. There is now a small but growing number of companies that act as supranational entities and arbitrage their national footprints according to their corporate interests (see Case Study 2: The rise of the private sector in science diplomacy).

This is possible in part because of the vast assets commanded by individual companies. For instance, if Microsoft and Apple were countries, they would be among the richest in the world. Along with their economic influence, these companies have cultivated their political influence – both nationally and multilaterally. For example, Microsoft has teams around the world focused on engaging with the UN, the EU, and the international system at large, based across New York, Geneva, Paris, Brussels, and Washington.

Recognising the growing power of industry, some countries have started opening diplomatic premises close to industrial headquarters. In 2017, Denmark established a tech embassy in Palo Alto, California. It was the first to do so, but has been followed by the EU Office in Silicon Valley, California; countries increasing their engagement with the technology sector through their California consuls general, and a newly appointed Envoy on Technology to the UN Secretary General.

There is now a small but growing number of companies that act as supranational entities.

> Without a basic level of mutual understanding between scientists and diplomats, there is a gap in effective communication.

This increasing global influence of industry has made international trade negotiations, and the role of science within them, even more complex and ambiguous. Trade is increasingly characterised by a vast increase in the use of data across national borders[53], and the rapid use of AI and associated new technologies. This has led to clashes with and between long-established value systems[54], such as the EU's prioritisation of its citizens' rights through the General Data Protection Regulation (GDPR), the US's constitutional commitment to free speech via the First Amendment, and the approach of many nations to deploying innovation in service of their own national interests.

The private sector is now a major funder of fundamental and applied science efforts in many countries. Major tech companies such as Amazon, Alphabet, Apple, Huawei, Meta, Microsoft and Samsung spend tens of billions of dollars each on R&D, including $85 billion by Amazon alone, according to 2023 figures[55]. This can include technical infrastructure that underpins critical emerging technologies (for example, quantum computing and AI). The control of these technologies, of course, exists outside governments, which represents a massive shift away from the high level of government control over previous technologies that had the potential to alter geopolitics and become the basis for conflicts (for example, nuclear weapons). This increased role of the private sector has resulted in cases where companies have developed essentially diplomatic relationships, including conversations about emerging technologies, with foreign governments – without the inclusion of national diplomats.

The blurred lines between scientific and national interests

With the increased attention on science diplomacy, there is a critical need to clarify both its purpose and the objectives, tasks, and roles of the actors involved. For the different actors to work together effectively, scientists need a basic understanding of diplomacy, while policymakers and diplomats need a similar understanding of science. In both cases, formal training can be of great benefit. Without a basic level of mutual understanding between scientists and diplomats, there is a gap in effective communication that can lead to missed opportunities, ineffective initiatives, and loss of trust.

The blurring of the roles at any given time is not constructive and can even be counterproductive. It is important to begin with the understanding that diplomats act as representatives of governments, ministries, industry, or international organisations that are setting policies with international implications. Scientists need to interact effectively with professional diplomats and the governments they represent. It is important for scientists working to bridge gaps in policymaking to understand their role and not blur the line between scientists and diplomats.

However, there is an increasing cadre of diplomats who are fully scientifically trained, and are employed as diplomats by governments in foreign ministries and other departments. Their scientific training enhances their role as diplomats – for example, in negotiations about climate change or pandemic treaties. This is an important development in diplomacy[56].

Scientific and national interests are not always aligned. Scientific interests, as we have defined them, are best served by the sharing of knowledge, and national interests can be served in this way too – for example, when national governments are urgently seeking to understand the extent of worldwide biodiversity loss. However, there may also be times when the national interest requires that scientific knowledge be kept secret – for example, when it involves sensitive defence or national security information. Further, science and policy do not operate on the same timescale. Policymakers typically prioritise immediate needs, such as during a pandemic, over protracted emergencies such as climate change, as the link between cause and effect can be harder to demonstrate when the effects are felt more slowly. Science diplomacy needs to be undertaken on both timescales, which can complicate its efforts.

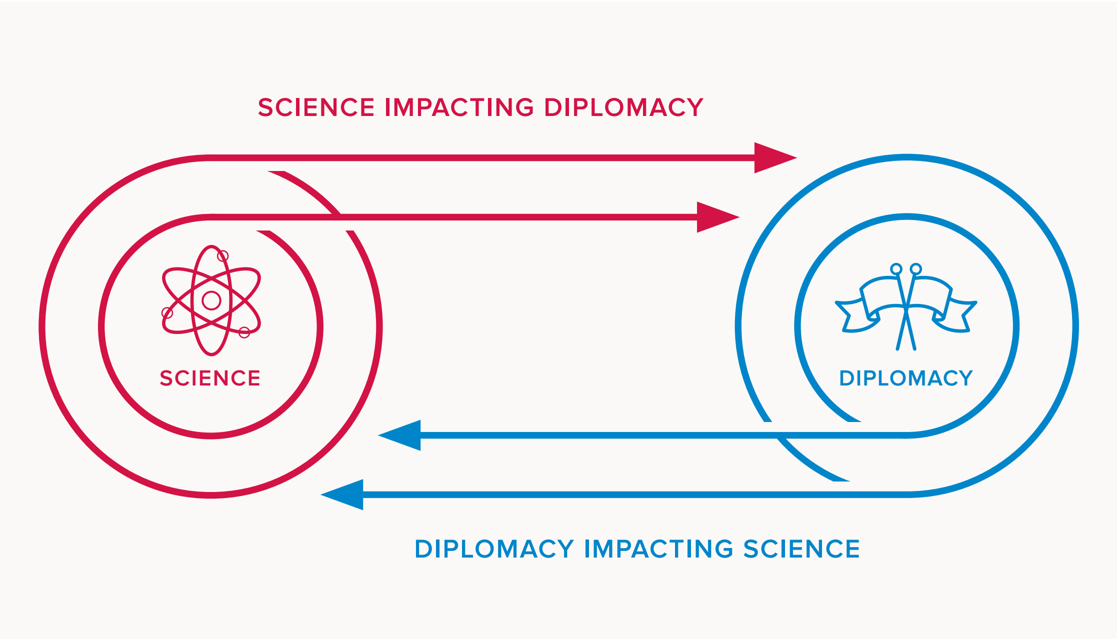
None of this discussion precludes scientists and the wider research community from seeking to influence governments through national and multilateral channels to optimise their use of science, evidence, and knowledge[57]. Scientists play a vital role in influencing foreign policy. However, it is ultimately the role of the policymaker – not the scientist – to decide on policies.

A new science diplomacy framework for the 2020s and beyond

The 2010 report laid out a conceptual framework for science diplomacy with three dimensions. In retrospect, and as it became apparent through our consultations for this report, these previous dimensions generated some confusion due to their similar wording and overlap in practice. This informed AAAS and the Royal Society's decision to present a simpler, broader framework. In essence, there are two entities at play – the field of science and the field of diplomacy. A science diplomacy framework must describe the multiple ways in which these two sectors interact. The Royal Society and AAAS suggest here a revised framework that has two dimensions: science impacting diplomacy and diplomacy impacting science.

This revised two-dimension framework is intended not to assert that there are only two ways for the fields to engage, but rather to create a more flexible definition that encompasses more forms of cooperation (or lack thereof) and is more adaptable to continuously changing scientific and geopolitical landscapes. Imagine a bridge with science on one side and diplomacy on the other, with different lanes connecting one side to the other. Collaboration can be initiated from the side of science or the side of diplomacy.

FIGURE 2



Science impacting diplomacy

As reviewed in this report, the need for science to play an active role in diplomacy is more important than ever. Science is critical to an increasing array of global challenges, including environmental, demographic, technological, and health-related. Finding solutions to all these challenges requires collaboration and partnership amongst nations, and cooperation amongst scientists – ideally, whether or not their home countries have good diplomatic relations – would be helpful in that regard.

All this could be categorised as science impacting diplomacy. This dimension clarifies, encompasses and expands the previous categories of science in diplomacy (scientific advice informing foreign policy) and science for diplomacy (scientific cooperation improving international relations) in the 2010 report. It includes advice from national scientific advisers or national academies, as well as advisory mechanisms such as the IPCC and those of other bodies within the UN system and multi-country efforts like the G7, the G20, or BRICS.

Diplomacy impacting science

Policymakers and diplomats have engaged more – not less – with science over the past 15 years and are active in conversations around scientific collaboration and international science policy. For example, policymakers and stakeholders outside science, such as intelligence agencies, are active members in the conversation around research security – namely, how to balance national security concerns with the value of open science. This conversation will likely intensify in the current geopolitical environment.

Non-scientific policymakers are also more involved in treaties around what were previously seen as global commons and thought to be primarily the domain of scientists. But changing geopolitics have demonstrated that some tools in the diplomatic toolkit affect science beyond just facilitating international science. Diplomacy has an important role in enabling more effective internationally collaborative science to flourish, while also putting in place 'guardrails' to safeguard or advance national or economic interests, including protecting research security and negotiating trade deals.

Diplomacy has an important role in enabling more effective internationally collaborative science to flourish.

The new diplomacy impacting science dimension encompasses and can be used to illustrate the many forms that this interaction can take. Diplomacy can help facilitate international science cooperation through activities such as major international scientific infrastructure programmes such as CERN, bilateral or multilateral summits on science issues; establishing government-level agreements on joint funding to facilitate research; and ensuring visas for visiting scientists. All these activities shape the dynamics of international collaboration – particularly as countries prioritise funding for and access to those parties they perceive to be allied or like-minded.

However, diplomacy impacting science also encompasses the use of diplomatic tools that can limit scientific cooperation, which countries may do if it aligns with their national interests. This may include the use of sanctions that could hinder scientific collaboration and restrict visiting scholars or students from certain countries, as well as restrictions on government science funding if institutions accept money from or work with certain countries. It also includes government-to-government agreements on research collaborations that are established not necessarily to advance science but rather to improve relations with another country (perhaps in competition with a third country).

Another key aspect of diplomacy impacting science is the way it utilises the soft power of science – for example bringing together scientists from different parts of the world to advance science and, in doing so, strengthening international relations. Science diplomacy also encompasses so called 'track-two' diplomacy. This is a form of informal diplomacy comprising international dialogues between diverse actors from sectors including business, academia, culture, the public sector, philanthropy, think tanks and journalism, and includes politicians and diplomats. Such meetings can bring new ideas and new relationships to the official process of diplomacy, particularly because these dialogues include leading thinkers who reside outside official governmental processes, and they increasingly include scientists and other researchers.

How science diplomacy should evolve and respond

Science and policymaking

The most critical underlying principle in the practice of science diplomacy, whether it be science impacting diplomacy or vice versa, is the necessity of a clear and unbiased presentation of evidence for policymaking. As this report notes, trust in science and in the use of evidence in policymaking is under renewed attack in many countries, exacerbated by the politicisation of science advice (for instance, during the pandemic)[58]. Therefore, practitioners of science diplomacy must ensure that their advice to policymakers is driven by fair and robust assessments of the best available evidence, accompanied by clarity about what is not known and what is uncertain.

Those involved in science diplomacy must also understand that scientific advice is not the only consideration for policymakers, and it will likely be just one of many factors that go into political decisions. When deciding on policies, politicians typically look through the lenses of evidence, policy deliverability, and values. Scientific evidence is the same the world over, but the value systems that synthesise it vary greatly.

The lens of values often overrides the others in influencing the nature of policy decisions by politicians, who are the principal policymakers in most nations. That is the nature of politics. However, scientists have not been helped in such cases by policymakers who avoid making difficult policy decisions because of false claims that the science is wrong or uncertain where it is not, who treat evidence as irrelevant or a nuisance, or who deny such evidence as a way of deferring decisions. Ideally, science should not be used as a cover for political decisions that are made on the basis of values. These principles and processes for international policymaking are no different from the provision of science advice for policymaking in individual national contexts[59].

For science diplomacy to be effective, scientists must interact regularly with professional diplomats and the governments they represent. It is important for scientists in advisory roles not to overstep the boundary between science advice and policymaking, for example, by advocating openly for a particular diplomatic or policy outcome. It is unreasonable to expect them not to have their own opinions, but these should be shared with honesty and acknowledgement of their limitations[60].

There are many models and avenues for providing scientific advice as well as other mechanisms to elevate the role of science in policymaking. Depending on the government system they are operating in, a scientist could play a purely advisory role, could be more directly involved in policy creation and implementation, or could wear multiple hats. At any given time, due to the diversity of their roles in different governments and/or over the course of their careers, scientists must understand and be transparent about their responsibilities and which role they are performing. Failure to do so comes with the potential to damage the vital relationships between scientists and diplomats and scientists and the public.

Nevertheless, there is a growing cadre of professional diplomats with full scientific training, who are working for governments around the world. These diplomats bring not only their own expertise, but also a deep understanding of the scientific method and, often, access to wide networks of expert advisers. This welcome development offers important value in all areas of science diplomacy.

> The most critical underlying principle in the practice of science diplomacy is the necessity for clear and unbiased presentation of evidence for policymaking.

> It is vital that there is no perception of naivete in the S&T sector's approach to cooperation.

National security

Other key aspects of science diplomacy need to change to meet the challenges of today and tomorrow. First, in a period of rising tensions between states, the national security implications of international scientific collaboration cannot be ignored. A key challenge for the foreseeable future will be to define the space where fruitful cooperation is possible between nations. It will be up to scientists to make their case as policymakers move forward on this while recognising that policymakers will oppose any cooperation that risks damaging national security interests.

Here, the need to consider the intentions of potential research partners and their networks is critical, as is clarity on the specific nature of individual risks. For example, is there potential for the research to be used elsewhere in ways unintended by the original researcher? Is there a risk that taxpayer-funded research may be given to a geopolitical rival or used for purposes against the country's interests? Equally, organisations involved in scientific cooperation, from academies to research funding organisations, will need to make the case that broadly defined bans on cooperation within large areas of scientific research can do more harm than good by blocking the economic, scientific, and diplomatic benefits that such relationships can bring.

Second, participants in science diplomacy will need to increase their awareness of these risks and demonstrate that they are responding to them. It is important that training is available for scientists on how diplomacy works and how to navigate international collaborations, while being mindful of national security risks. That does not mean that all scientists need to become experts in international relations – as previously stated, not all international collaboration is science diplomacy – but it is vital that there is no perception of naivete in the S&T sector's approach to cooperation.

Third, science diplomacy practitioners need to recognise that the practice of diplomacy by definition, will always involve the pursuit of national interests. In many areas where science is deeply embedded in the diplomatic effort (for example, climate negotiations) these interests could align with what might be described as the 'global good.' But these interests can also diverge. In these circumstances, scientists working in diplomatic spaces must recognise that a diplomat's role is to act in their government's interest, and when that interest diverges with scientific advice, the policies and priorities of the nation they represent will typically come first.

National interests

Furthermore, it is also reasonable for national governments to enlist the science they fund in the promotion of these national interests, albeit within limits. Rising nationalism and authoritarianism around the world increase the risk of science being misused for ideological ends (as it was in the previous century, with appalling consequences). Both scientists and diplomats must recognise where the boundaries lie between the role of adviser and the political decisions that are taken in response in order to ensure that trust between scientific advisers and policymakers is preserved and enhanced.

Scientists will need to balance a hard-headed, realistic approach to future collaborations with appreciation of the need for clear ethical guidelines. The complex nature of today's technologies and the fragmented world in which they are developed offer new challenges. For example, a number of initiatives are already being developed around the ethics and safety of AI[61].

Global commons

Science diplomacy will also need to be at the forefront of a renewed approach to global commons. The treaties governing the polar regions, space, and the deep ocean are often held up as successful examples of science diplomacy. But in all these areas, the ideals supporting freedom of scientific research are coming into conflict with sovereign national interests, mostly pertaining to defence or economic advantage. As global commons become increasingly accessible, careful work is needed to ensure science is not used as a proxy in national efforts to assert dominance or control over a particular nation or region.

Inclusivity

Finally, it is vital that international scientific collaboration is inclusive. This must include perspectives from the Global South, with scientists and communities included as equal partners and co-designers of scientific collaborations. Organisations such as the Global Science Forum for the OECD, Southern Voice, TWAS, and the Global Young Academy are potent advocates for capacity development, more equitable partnerships, and fairer global research collaborations. All these organisations, and many more like them, have a key role to play in ensuring a wide diversity of voices inform work at the interface between science and diplomacy. At least some of these voices will also inevitably bring different views and values to the table – differences that will need to be recognised and reconciled.

International scientific collaboration must include perspectives from the Global South, with scientists and communities included as equal partners and co-designers of scientific collaborations.

Conclusion

Science diplomacy is one of many tools used to achieve the objectives of those pursuing statecraft.

We are entering an era when the fields of science and diplomacy have changed in fundamental ways, the world is facing significant challenges, and the geopolitical context is becoming increasingly fragmented, contested, and unstable. Science diplomacy is needed more than ever, as is a renewed framework to ensure its continued utility.

Above all else, science diplomacy is a practical activity in an imperfect world. Burying it in complex theoretical frameworks is of no value. The key attributes for scientific participants in diplomatic processes are a depth and breadth of scientific expertise backed by strong supporting networks, excellent communication skills, understanding of government processes, and respect for the boundaries between scientific evidence and policymaking.

The key attributes for diplomats and other policymakers are a recognition of the importance and value of rigorous scientific evidence and analysis in developing, deciding, and implementing policies, as well as a strong network of scientific contacts. This includes an appreciation of what is known with a high degree of confidence, as well as what is uncertain and what is not yet known or unknowable. It requires a recognition that scientific knowledge continually advances and requires reassessment. Policy decisions that ignore or go against the implications of scientific findings should not be explained away by false claims about the strength of the evidence. Trust underpins effective diplomacy, and trust is earned through actions that build it.

This report acknowledges that science diplomacy is one of many tools used to achieve the objectives of those pursuing statecraft. However, as this report discusses, there has been a rising trend of non-state actors, including industries and tech titans who are pursuing their own versions of statecraft; these parties use science diplomacy as one tool to achieve their objectives, which may or may not be in line with their country's national interests. Additionally, individuals may be using science diplomacy in pursuit of institutional goals. Throughout the report, therefore, the concept of national interests should also be recognised as referring in some cases to self-interest or institutional interests.

This report sets out a revised framework which provides a purpose, objectives, and goals for the field of science diplomacy, while remaining simple and flexible enough to adapt to changing scientific, diplomatic, and geopolitical landscapes. We welcome continued discussion on the concept of science diplomacy, the different ways that the fields of science and diplomacy interact, and most important, how science diplomacy is practised.

CASE STUDY 1

The Arctic

One of the more prescient passages in the 2010 report identified the inherent difficulties of governing international spaces and argued that competition between states "could intensify as previously inaccessible regions, such as the Arctic Ocean, open up as a consequence of climate change"[62]. The Arctic region therefore provides a good lens through which to consider the role of science diplomacy as it adapts to the geopolitical changes within the region.

The Arctic region has been described as one of several "shared international spaces…beyond or at the edges of national jurisdiction"[63]. Unlike its opposite pole in the south, the Arctic Ocean is surrounded by continental landmasses and sovereign states, with a population of approximately 4 million people living within the Arctic Circle[64].

Formed in 1996, the Arctic Council is a soft-law regime that brings together representatives from the Arctic States, Indigenous peoples, and other observers to address the shared issues facing the region, operating within a context of various bilateral and multilateral treaties between sovereign states[65]. It promotes the peaceful uses of science in the region (see Section 3) and provides a way for the Arctic States to work together to address shared problems[66]. It has no power to enforce laws, and some representatives and observers may have limited participation[67].

The governance of the Arctic region is further complicated by the international status of the Arctic Ocean, which is primarily governed under the UN Convention of the Law of the Sea (UNCLOS)[68]. Despite clear legislation identifying state boundaries and which activities are permitted in the region as a whole, the combined lack of enforcement and perceived uncertainty around international borders creates a space which is open to abuse; maritime borders are notoriously hard to police, and it is becoming increasingly advantageous for some states to simply ignore or claim uncertainty over territorial boundaries[69].

The vulnerabilities of this system of governance are becoming increasingly obvious to international observers[70]. Like many other shared international spaces[71], the limited powers of Arctic-region governance reflect a historic view of the area as too inaccessible and inhospitable for the exploitation of its natural resources to be worth the effort. With little incentive for the Arctic States to strictly protect borders, international activity was largely left to scientists[72]. Notably, even within clearly demarcated territorial boundaries, legislation protects rights of access for international entities for purposes of research, demonstrating the acceptance of international scientific endeavours in this area[73].

CASE STUDY 1 (CONTINUED)

Yet in recent years the exploitability of this status quo has become apparent. The effects of climate change and the impact of technological development and distribution have made the Arctic more accessible to governments, companies, and wealthy private individuals[74].

Further, the recognition of the Arctic region's untapped natural resources has firmly located it within the foreign policy strategies of states[75]. Treaties designed prior to these developments, which sought to promote international scientific collaboration, are no longer sufficient to manage the changing significance of the Arctic region. The region now presents commercial opportunities in the form of deep sea-mining, mineral deposits, and the Northwest Passage, which is opening up as a result of climate change. In the context of increasing global tensions, restrictions on travel between Russia and the West, resource scarcity, and, in places, outright war, these opportunities are inherently political. Within this context, the concept of a scientific endeavour is open to misuse or vulnerable to being perceived as a stalking horse through which wider strategic, economic and political goals can be realised.

Examples of this were already apparent nearly two decades ago. The Artika 2007 expedition saw a Russian flag planted on the seabed at the North Pole, ostensibly during the course of scientific research, intended to substantiate Russian claims that their Arctic territory should extend to the pole. If recognised by the international community, the claim would have added a large slice of the Arctic region, along with its oil and gas deposits, to Russian state control. Denmark and Canada have employed similar strategies in attempts to expand their Arctic-region territories[76].

In recent years, contestation of the Arctic region has progressed from theoretical arguments to active incidents of sabotage to key infrastructure[77]. Growing interest in the increasingly accessible Northwest Passage has made the Arctic States anxious to assert their sovereignty over as much of the area as possible[78]. Further, economic interests drive much of the renewable energy development and engineering within the Arctic region. Another important political dimension is advocacy by and on behalf of the Indigenous peoples of the region, many of whose livelihoods and traditional practices are hindered by the nation-state system of contested borders[79].

The lessons from the Arctic region demonstrate how the context within which science diplomacy operates is ever-changing; areas considered the neutral domain of science today can become geopolitically significant tomorrow. Because of this, efforts at scientific collaboration must be performed with eyes wide open. Just as they do when ensuring research security[80], researchers should consider the intentions of those they collaborate with, who is backing them, and how they might change in the future. Along with diplomats needing a level of scientific fluency, scientists working in these increasingly contested spaces need to have some fluency in diplomacy and geopolitics; science as a politically neutral endeavour no longer applies to the Arctic region – if it ever did.

CASE STUDY 2

The rise of the private sector in science diplomacy

In the past 15 years, the private sector has wielded increasing influence on foreign policy. This phenomenon is not unprecedented: In the 19th century, the East India Company actively participated in geopolitics and and controlled a private army larger than that of many nations[81]. In the US, industrial leaders in the late 19th and early 20th centuries amassed more wealth than the US Treasury and played active roles in foreign policy, including funding conflicts in foreign countries.

A notable feature of our times is both increasing investment in R&D from the private sector and an increasing concentration of this spend within a small number of firms.

The amplified role of the private sector is seen across different industries. For example, the US pharmaceutical industry spent over $80 billion on R&D in 2019. Adjusted for inflation, this figure was 10 times what the industry invested in the 1980s[82] a function of both the increasing costs of drug discovery and the general increase in private-sector R&D. Increased private-sector investment in R&D is seen across other leading scientific nations, including Japan, Germany, South Korea, the UK, and France. In China, private-sector investment in R&D has almost doubled in the past 30 years and now vastly outweighs that of the public sector[83].

More recently, a small number of firms have emerged that each have research budgets comparable to those of many midsized national economies: In 2022, the annual R&D expenditures of Amazon, Meta, Alphabet, Apple, Huawei, and Microsoft were all over $20bn[84].

This concentration of R&D in the private sector can pose challenges for public access to research when companies have widely varying approaches to publishing data and literature.

Concerns over private-sector influence in R&D may be further exacerbated by companies' control of scientific infrastructure, especially where technology has national and international applications. A supranational[85] private entity that has excessive control of critical infrastructure –including in some cases direct control over the use or non-use of those technologies – brings up questions of accountability and new issues for the global governance of technology. These challenges to accountability are especially notable for supranational companies that can exploit different national policy systems to globally arbitrage taxation regimes and potentially avoid mechanisms of accountability, including national laws, regulations and standards.

While the role of the private sector in developing and owning infrastructure is well established, there is an increasing trend towards exclusive and private control. This is seen, for example, in the 'compute divide', where the proportion of large-scale AI research run by academics has fallen from almost 60% in the 2010s to almost 0% in 2024[86]. This divide narrows the diversity of research on this critical emerging technology, allowing for a small number of leading companies to effectively monopolise its development. As a consequence of this, AI R&D (whether publicly or privately funded) must work within an architecture heavily dependent on access to industrially funded infrastructure.

CASE STUDY 2 (CONTINUED)

The model where the private sector either partners with or sells its work to the public sector is also evolving, to one where private firms retain ultimate control of a final product. Private enterprise was critical in the development of the GPS network, for example, but the satellite system itself is owned and operated by the US government. In comparison, the provision of internet connectivity to the Ukrainian military is through a private company (Starlink, run by SpaceX), whose executive team members have themselves decided where the technology can be used. This presents the risk that private commercial interests might be prioritised over the interests of nation-states.

Technologies of war, once they had been procured, were previously controlled by national militaries. For example, nuclear weapons and their infrastructure historically have been under the purview of national leaders, who represent their governments in international agreements and treaties.

This is not the case with the infrastructure of emerging technologies, which raises implications for any future international agreements on the use of these technologies, as private entities often sit uncomfortably within established treaty-making processes.

The present-day rise of the so-called tech titans challenges the notion that in science diplomacy the only diplomatic actors are nation states acting in their own national interest. A small number of 'supranational' companies, while not actual states, have nonetheless become diplomatic actors and pursued their own forms of statecraft, which may put them at odds with the countries where they are headquartered. For example, the Chinese government's crackdown on Alibaba may have been motivated in part by recognition of the company's potential to act counter to government policies[87].

We are living in a complicated world where diplomatic efforts by nation-states and private companies are becoming intertwined. Companies have representational offices at the UN and countries have embassies and offices in technology and innovation hubs, such as Silicon Valley. Nations and industries will continue to be connected, but the dynamics of their relationship, and whether countries and multilateral organisations will start treating supranational companies as de facto nation states – is less clear.

APPENDIX 1

Further details on methodology

Evidence gathering

The report draws on over a year of evidence gathering and the Royal Society and the AAAS would like to thank all those who contributed to the development of this project. In addition to the high-level scientific meetings listed below, a joint special issue of the AAAS journal *Science & Diplomacy* was commissioned, with perspectives from around the world, and including new critiques and refinements of the concept of science diplomacy[88]. Together, these initiatives convened a wide range of experts and stakeholders from around the world including leaders in government, science academies, higher education, industry and other sectors.

List of events

Disclaimer: the titles and organisations of the individuals listed below reflect their position at the time the listed event took place.

Science diplomacy – 15 years on, London, November 2023

A high-level roundtable held at the Royal Society which considered what science diplomacy means in today's world, and in what ways it needs to be reframed.

Participants	
Sir Mark Walport FRS FMedSci (Chair)	Foreign Secretary, Royal Society
Dr Sudip Parikh	CEO of AAAS and Executive Publisher of the Science family of journals
Fiona Clouder	Chief Executive, ClouderVista; former British Ambassador to Chile; Regional Ambassador for Latin America and the Caribbean for COP26
Dr Laura Greene	Chief Scientist, National High Magnetic Field Laboratory; member of President Biden's Council on Advisers on Science and Technology (PCAST); former APS President
Dr Margaret Hamburg	Co-president of InterAcademy Partnership; former U.S. Commissioner on Food and Drugs; former Foreign Secretary, National Academy of Medicine; former AAAS President; Founding Vice President for Biological Programs at the Nuclear Threat Initiative
Dr Tolullah Oni	Clinical Professor of Global Public Health & Sustainable Urban Development, University of Cambridge; former Co-chair, Global Young Academy
Dr Allison Schwier	Deputy Director, Office of the Science and Technology Adviser to the US Secretary of State, US Department of State
Professor Charlotte Watts FMedSci	Chief Scientific Adviser, Foreign Commonwealth and Development Office
Sir Chris Whitty KCB FRS FMedSci	Chief Medical Officer for England and Chief Medical Adviser

AAAS annual meeting, Denver, February 2024
Session on science diplomacy at the AAAS Annual Meeting in Denver in February 2024.

International Network of Government Science Advice (INGSA) conference, Kigali, May 2024
On 3 May 2024, the American Association for the Advancement of Science (AAAS), the European Commission, the Geneva Science and Diplomacy Anticipator (GESDA) and the Royal Society convened a satellite event at the INGSA conference in Kigali, to consider how the core concepts of science diplomacy should be updated to help address pressing global issues effectively. Participants were asked to consider how the scientific and diplomatic landscapes have changed and how the concept of science diplomacy should evolve to reflect this changing environment.

Participants	
Dr Christian Acemah	Executive Director, Uganda National Academy of Sciences
Ikirezi Anitha	African Leadership University
Dr Anna-Maria Arabia	Chief Executive, Australian Academy of Science
Dr Salvatore Arico	CEO, International Science Council
Kana Asano	Fellow, Center for Research and Development Strategy, Japan Science and Technology Agency (JST)
Professor Tateo Arimoto	Senior Adviser to the President of Japan Science and Technology Agency
Dr Akeem Babatunde	Nigerian Young Academy
Dr Laurent Bochereau	Minister-Counsellor, Delegation of the European Union to the African Union
Dr Adriana Castaño	Member of Steering Committee, INGSA Latin America – Caribbean
Lila Chibane	Research Director, Center Research Economy Applied Pour Le Développement-Cread (CREAD), Algeria
Luke Clarke	Head of International Affairs (Americas, International Organisations and Africa), Royal Society
Dr Gavin Costigan	Chief Executive, Foundation for Science and Technology
Dr Thierry Damerval	Managing Director, French National Research Agency (ANR)
Fran Davies	Head of Global Science, UK Foreign, Commonwealth and Development Office (FCDO)
Agnieszka Gadzina-Kolodziejska	Deputy Head of the Science for democracy and evidence-informed policymaking Unit, JRC
Dr Daan du Toit	Acting Director-General, South African Department of Science and Innovation

Participants (continued)	
Sir Peter Gluckman FRS, FMedSci	President, International Science Council
Dr Patricia Gruber	Science and Technology Adviser to the US Secretary of State
Dr Nick Hart	President, Data Foundation
Dr Maggy Heintz	Executive Director, UK Collaborative on Development Research
Niccolò Iorno	Scientific Advisor, Science Diplomacy, Federal Department of Foreign Affairs, Switzerland
Maria Jarquin	International Relations Coordinator, UK Centre for Ecology and Hydrology
Dr Motoko Kotani	Science and Technology Advisor, Minister of Foreign Affairs of Japan
Kathrin Kohs	Programme Director, Deutsche Forschungsgemeinschaft (DFG)
Professor Lise Korsten	President, African Academy of Science
Professor Yoichiro Matsumoto	Science and Technology Advisor, Minister of Foreign Affairs of Japan
Dr Sofía Mazariegos	Deputy Director, Organization for Women in Science in the Developing World (Guatemala chapter)
Dr Chomora Mikeka	Director of Science, Technology and Innovation, Ministry of Education, Malawi
Dr Alma Cristal Hernández Mondragón	President, Mexican Association for the Advancement of Science (AMEXAC)
Dr Kim Montgomery	Director of International Affairs and Science Diplomacy, AAAS
Dr Jan Marco Müller	Coordinator for Science Diplomacy and Multilateral Relations, DG Research and Innovation, EC
Dr Jean-Christophe (JC) Mauduit,	Associate Professor of Science Diplomacy, University College London (UCL)
Professor Romain Murenzi	Professor of Physics, Worcester Polytechnic Institute (WPI)
Dr Oladoyin Odubanjo	Executive Secretary, Nigerian Academy of Science
Dr Philip Osano	Centre Director, Stockholm Environment Institute (SEI) Africa
Dr Liliana Pasecinic	Deputy Head of Unit, Joint Research Centre, European Commission
Dr Alícia Pérez-Porro	Deputy Director / Scientific Coordinator, Ecological and Forestry Applications Research Centre
Professor João Pinto	Professor of Diplomacy, University of Minho, Portugal

Participants (continued)	
Professor Mu Rongping	Director-General and Professor of the Institute of Policy and Management, Chinese Academy
Dr Elizabeth Silvestre	Senior Environmental Science and Policy Advisor / Climate Change Consultant
Dr Marga Gual Soler	Head of Science Diplomacy Capacity Building, GESDA
Dr Nathalie Tremblay	Digital Health and MedTech Advisor, Fonds de recherche du Quebec
Dr Vaughan Turekian	Executive Director, Policy and Global Affairs Division (PGA), National Academy of Sciences (NAS)
Dr Eva Liliane Ujeneza	Senior Lecturer, Rwanda Institute for Conservation Agriculture
Professor Charlotte Watts FMedSci	Chief Scientific Adviser, UK Foreign, Commonwealth and Development Office
Ian Wiggins	Director of International Affairs, Royal Society
Professor James Wilsdon	Professor of Research Policy, University College London

Knowledge diplomacy – the role of international higher education in a new geopolitical era, Wilton Park, June 2024

This dialogue sought to explore this concept amid a rapidly changing global landscape, highlight how higher education institutions (HEIs) and similar stakeholders are adopting it, and outline some recommendations for future collaboration so that together they can use it to help shape a future where international relations, higher education and research are most effectively optimised to address the critical global challenges facing the world today. It brought together 40 leaders from 16 different countries from sectors including higher education, research funders, government, diplomacy, industry, national scientific academies, and other organisations to discuss these and related issues in what is intended to be the beginning of an ongoing conversation.

Science and technology diplomacy – Science, Technology and Society (STS) forum,
Kyoto, October 2024

Co-hosted by Sudip Parikh, Chief Executive Officer of AAAS, this session focused on the changing scientific and diplomatic landscapes and what that means for science and technology diplomacy moving forward. The discussion addressed the role of science and technology diplomacy in meeting governmental objectives, how international scientific collaboration may be impacted by the complex geopolitical environment, and how science and technology diplomacy can be utilised in the global commons.

Chair and Speakers	
Dr Sudip Parikh (Chair)	Chief Executive Officer, American Association for the Advancement of Science (AAAS), USA
Dr Nardos Bekele-Thomas	Chief Executive Officer, African Union Development Agency (AUDA-NEPAD)
Dr Dave Smith	National Technology Adviser, Department for Science, Innovation and Technology, UK Government, UK
Professor Takao Someya	Professor, The University of Tokyo, Japan
Dr Vaughan Turekian	Executive Director, Policy and Global Affairs Division (PGA), National Academy of Sciences (NAS); former Science and Technology Adviser to the Secretary of State, Department of State, USA
Professor K Vijayraghavan FRS	Former Principal Scientific Adviser to the Government of India, National Centre for Biological Sciences; DAE Homi Bhabha Chair, National Centre for Biological Sciences, TIFR, India

Advancing science diplomacy through the international decade of sciences for sustainable development – world science forum, Budapest, November 2024

This session examined the nuanced relationship between science diplomacy and the broad objectives of the International Decade of Sciences for Sustainable Development (IDSSD). It provided an overview of how science diplomacy operates and its critical role in achieving the Sustainable Development Goals (SDGs). Emphasizing the IDSSD, the discussion underscored the importance of this initiative in fostering global scientific cooperation and bolstering diplomatic relations. The session aimed to showcase how international collaborations in science, exemplified by research infrastructures like ICTP or SESAME as well as policy advisory bodies like IPCC or IPBES, can significantly advance diplomatic and sustainable development agendas by promoting peace, prosperity, and planetary health.

Speakers	
Professor Lidia Brito	Assistant Director-General for Natural Sciences, United Nations Educational, Scientific and Cultural Organisation (UNESCO)
Dr Jan Marco Müller	Team Leader Global Approach, Multilateral Dialogue and Science Diplomacy, European Commission
Sir Peter Gluckman FRS, FMedSci	President, International Science Council (ISC)
Csaba Kőrösi	President, 77th General Assembly of the United Nations
Professor Atish Dabholkar	Director, The Abdus Salam International Centre for Theoretical Physics (ICTP)
Dr Saja Al Zoubi	Co-leader of GYA At Risk Scholars Initiative, Global Young Academy
Dr Vaughan Turekian	Executive Director, Policy and Global Affairs Division (PGA), National Academy of Sciences (NAS)
Dr Peggy Oti-Boateng	Executive Director, African Academy of Sciences
Professor László Kollár	Secretary-General, Hungarian Academy of Sciences
Dr Ana Persic	Programme Specialist, UNESCO

APPENDIX 2

Acknowledgements

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Reviewers and review process

This report has been reviewed by expert reviewers, before being approved by Officers of the Royal Society. Reviewers were not asked to endorse the conclusions or recommendations of the report, but to act as independent referees of its content and presentation. Reviewers acted in a personal and not a representative capacity. The Royal Society gratefully acknowledges their contributions.

Reviewers	
Professor Salim Abdool Karim FRS	Director, CAPRISA (Centre For The Aids Programme Of Research In South Africa)
Sir Simon Fraser GCMG	Chair, Chatham House and former Permanent Under Secretary, Foreign Commonwealth and Development Office
Professor Charlotte Watts FMedSci	Chief Scientific Adviser, UK Foreign Commonwealth and Development Office
Sir Chris Whitty KCB FRS FMedSci	UK Chief Medical Officer
Professor Tateo Arimoto	Senior Adviser to the President of Japan Science and Technology Agency
Dr Daan du Toit	Deputy Director-General, International Cooperation, Department of Science and Innovation, South Africa
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References

1 Montgomery, K., Wiggins, I., 2024. The Special Issue: Science Diplomacy – 15 Years On. See https://www.sciencediplomacy.org/editorial/2024/special-issue-science-diplomacy-15-years (accessed 21 January 2025).

2 The American Association for the Advancement of Science (AAAS) and the Royal Society, 2010. New Frontiers in Science Diplomacy. See https://royalsociety.org/news-resources/publications/2010/new-frontiers-science-diplomacy/ (accessed 21 January 2025).

3 The Diplomatic Service of the European Union, 2022. Science Diplomacy. See https://www.eeas.europa.eu/eeas/science-diplomacy_en#:~:text=In%20fact%2C%20the%20term%20%E2%80%9Cscience,research%20and%20innovation%20as%20an (accessed 21 January 2025).

4 GESDA, 2021. Geneva Science Diplomacy Week. See https://gesda.global/sdw-immersion-program/ (accessed 21 January 2025).

5 The Rockefeller University, 2024. The Hurford Science Diplomacy Initiative. See https://graduate.rockefeller.edu/science_diplomacy (accessed 21 January 2025).

6 For a couple of examples see Foreign & Commonwealth Office and The Rt Hon Hugo Swire, 2015. The UK, Brazil and Science Diplomacy. See https://www.gov.uk/government/speeches/the-uk-brazil-and-science-diplomacy (accessed 21 January 2025). and Ministry of Foreign Affairs: Government of Pakistan, 2024. Talk on “Science Diplomacy and Development” by Ambassador of the Republic of Korea. See https://mofa.gov.pk/news/talk-on-science-diplomacy-and-development-by-ambassador-of-the-republic-of-korea-on-science-and-technology-followed-by-scientists-dialogue-2 (accessed 21 January 2025).

7 The European Union (EU) also uses the term in many different contexts and has been convening stakeholders to develop a “European approach to science diplomacy”. Council of the European Union and the European Commission, 2023. Towards a European framework for science diplomacy. See https://eu-science-diplomacy.service-facility.eu/en/outcome (accessed 21 January 2025). STIP Compass, 2023. National Science Diplomacy Strategy. See https://stip.oecd.org/stip/interactive-dashboards/policy-initiatives/2023%2Fdata%2FpolicyInitiatives%2F99997281 (accessed 21 January 2025). For examples of national science diplomacy strategies in Colombia, Panama, and Mexico, please see Representatives of the countries of the Americas present at the Science Diplomacy Forum in Panama, 16-21 October, 2023, 2023. Panama Declaration. See https://www.iai.int/en/post/detail/Panama-Declaration#:~:text=From%20Panama%2C%20one%20of%20the,to%20effectively%20address%20global%20challenges (accessed 21 January 2025); Zegbe, 2022. The Role of Mexico’s Public Diplomacy and Its Concomitant Connection to Culture and Wellbeing in the Context of MONDIACULT 2022. See https://stip.oecd.org/stip/interactive-dashboards/policy-initiatives/2023%2Fdata%2FpolicyInitiatives%2F99997281 (accessed 21 January 2025).

8 Olšáková, D., Robinson, S., 2022. Global Conflict and the Rise of ‘Post Naïve’ Science Diplomacy. See https://blogs.lse.ac.uk/impactofsocialsciences/2022/05/06/global-conflict-and-the-rise-of-post-naive-science-diplomacy/ (accessed 21 January 2025).

9 Cramer, K., Ngabonziza, P., Rüffin, N., Rüland, A.-L., Saxena, M., Skupien, S., 2023. Science diplomacy and the North-South divide: Lessons learned from Southern participation in intergovernmental science organizations. See https://era.ideasoneurope.eu/2023/06/29/science-diplomacy-and-the-north-south-divide-lessons-learned-from-southern-participation-in-intergovernmental-science-organizations/ (accessed 21 January 2025).

10 Andersen, C., Clopot, C., Ifversen, J., 2020. Heritage and interculturality in EU science diplomacy. and Ruffini, P.-B., 2020. Conceptualizing Science Diplomacy in the Practitioner-Driven Literature: A Critical Review. See https://www.nature.com/articles/s41599-020-00609-5 (accessed 21 January 2025).

11 Wolfe, A., 2018. Freedom’s Laboratory: The Cold War Struggle for the Soul of Science. United Kingdom: John Hopkins University Press. See https://audrawolfe.com/ (accessed 21 January 2025).

12 Montgomery, K., Wiggins, I., 2024. The Special Issue: Science Diplomacy – 15 Years On. See https://www.sciencediplomacy.org/editorial/2024/special-issue-science-diplomacy-15-years (accessed 21 January 2025).

13 Carrero-Martínez, F. A., Ohira, M., Matsumoto, C. E., 2024. Science Diplomacy in Latin America and the Caribbean: The Convergence of Science, Policy and Diplomacy to Solve Global Challenges. See https://www.sciencediplomacy.org/perspective/2024/science-diplomacy-in-latin-america-and-caribbean-convergence-science-policy-and (accessed 21 January 2025).

14 Jagadish, C., Separovic, F., 2024. Science Diplomacy in the Indo-Pacific: An Australian Perspective. See https://www.sciencediplomacy.org/perspective/2024/science-diplomacy-in-indo-pacific-australian-perspective (accessed 21 January 2025).

15 As defined by Collins English Dictionary. See https://www.collinsdictionary.com/dictionary/english/statecraft (accessed 24 January 2025).

16 Throughout the report we have used the language of national interests, but recognise that in some cases those are in self- or institutional interests.

17 Turekian, V., Gluckman, P., 2024. Science Diplomacy and the Rise of Technopoles. See https://issues.org/science-diplomacy-technopoles-turekian-gluckman/ (accessed 21 January 2025).

18 Gluckman, P., Grimes, R., Kishi, T., Turekian, V., 2017. Science Diplomacy: A Pragmatic Perspective from the Inside. See pragmatic_perspective_science_advice_dec2017_1.pdf (accessed 21 January 2025).

19 Bunn, E., Ledgerwood, C., 2022. Science Diplomacy. See https://post.parliament.uk/science-diplomacy/ (accessed 21 January 2025).

20 Wilton Park, 2024. Knowledge Diplomacy: The Role of International Higher Education in a New Geopolitical Era. See https://www.wiltonpark.org.uk/event/knowledge-diplomacy-the-role-of-international-higher-education-in-a-new-geopolitical-era/ (accessed 21 January 2025).

21 Gilbert, N., Mallapaty, S., 2024. US and China Sign New Science Pact – But With Severe Restrictions. See https://www.nature.com/articles/d41586-024-04175-7 (accessed 21 January 2025) and Karplus, V. J., Xue, L., Morgan, M. G., He, K., Victor, D. G., Zhang, S.-N., 2025. How to Sustain Scientific Collaboration Amid Worsening US–China Relations. See https://www.nature.com/articles/d41586-025-00033-2 (accessed 21 January 2025).

22 For two contemporary accounts of the challenges of science diplomacy in these countries and regions, see Beldengrün, A., Prawer, E., Khweis, M., 2024. Science Diplomacy in Troubled Times: What the Israeli-Palestinian Conflict Teaches Us About Science Diplomacy. See https://www.sciencediplomacy.org/perspective/2024/science-diplomacy-in-troubled-times-what-israeli-palestinian-conflict-teaches-us (accessed 21 January 2025) and Dobko, T., 2024. On the Role of Universities in Science Diplomacy for Ukraine. See https://www.sciencediplomacy.org/perspective/2024/role-universities-in-science-diplomacy-for-ukraine (accessed 21 January 2025).

23 Pitteloud, J., 2024. Not Lost in Translation: Science Diplomacy in a Brave New World. See https://www.sciencediplomacy.org/perspective/2024/not-lost-in-translation-science-diplomacy-in-brave-new-world (accessed 21 January 2025).

24 Müller, J. M., 2024. Building European Science Diplomacy from the Bottom Up. See https://www.sciencediplomacy.org/perspective/2024/building-european-science-diplomacy-bottom (accessed 21 January 2025).

25 Beacháin, D., Polese, A. (Eds.), 2010. The Colour Revolutions in the Former Soviet Republics: Successes and Failures.

26 Reic, I., Villafana, T., Alfredsson, P., Hubben, S., 2024. The Role of the Private Sector in Science Diplomacy: Lessons from COVID-19. See https://www.sciencediplomacy.org/perspective/2024/role-private-sector-in-science-diplomacy-lessons-covid-19 (accessed 21 January 2025).

27 The Royal Society, 2019. UK Science and Immigration: Why the UK Needs an Internationally Competitive Visa Offer. See https://royalsociety.org/news-resources/publications/2019/uk-science-and-immigration-why-the-uk-needs-an-internationally-competitive-visa-offer/ (accessed 21 January 2025).

28 The Royal Society, 2022. The Online Information Environment. See https://royalsociety.org/news-resources/projects/online-information-environment/ (accessed 21 January 2025).

29 Nature news team and freelance reporters, 2026. The Israel–Hamas Conflict: Voices from Scientists on the Front Lines. See https://www.nature.com/articles/d41586-023-03550-0 (accessed 21 January 2025).

30 Noorden, R. V., 2023. Data Hint at Russia's Shifting Science Collaborations After Year of War. See https://www.nature.com/articles/d41586-023-00552-w (accessed 21 January 2025).

31 The Royal Society, 2022. The Online Information Environment. See https://royalsociety.org/-/media/policy/projects/online-information-environment/the-online-information-environment.pdf (accessed 21 January 2025).

32 These are often referred to in shorthand as 'helicopter' or 'parachute' science – when researchers from higher-income settings carry out research in resource-poor settings with limited to no involvement of local communities or researchers.

33 When the World Conference on Research Integrity was held in Africa for the first time in May 2022, Cape Town, researchers from across the continent and around the world dedicated several sessions to addressing these issues, leading to the Cape Town Statement on Fostering Research Integrity through Fairness and Equity, a crucial and influential piece of guidance for the global scientific community. Alba, S., Gopalakrishna, G., Horn, L., Kleinert, S., Kombe, F., Lavery, J. V., Visagie, R. G., 2023. The Cape Town Statement on Fostering Research Integrity Through Fairness and Equity Advocates. See https://www.wcrif.org/guidance/cape-town-statement (accessed 21 January 2025).

34 Dawes, J., Salt, K., Smith, C., 2024. Achieving Research Security While Pursuing Science Diplomacy: Considering Intentionality. See https://www.sciencediplomacy.org/perspective/2024/achieving-research-security-while-pursuing-science-diplomacy-considering (accessed 21 January 2025).

35 Sidik, S. M., 2022. Weaving the Lore of the Land Into the Scientific Method. Nature, 601, pp. 283-287. See https://media.nature.com/original/magazine-assets/d41586-022-00029-2/d41586-022-00029-2.pdf (accessed 21 January 2025).

36 The Royal Society, 2024. Science in the Age of AI: How Artificial Intelligence Is Changing the Nature and Method of Scientific Research. See https://royalsociety.org/-/media/policy/projects/science-in-the-age-of-ai/science-in-the-age-of-ai-report.pdf (accessed 21 January 2025).

37 See https://www.ropesgray.com/en/insights/alerts/2024/07/final-issuance-of-federal-guidelines-for-security-in-scientific-research-impact-on-universities (accessed 24 January 2025).

38 Australian Government: Department of Education, 2024. Guidelines to counter foreign interference in the Australian university sector. See https://www.education.gov.au/guidelines-counter-foreign-interference-australian-university-sector (accessed 21 January 2025).

39 Cabinet Office, Government of Japan, n.d. Research Integrity. See https://www8.cao.go.jp/cstp/english/about/research_integrity.html (accessed 21 January 2025).

40 G7, n.d. G7 Common Values and Principles on Research Security and Research Integrity. See https://science.gc.ca/site/science/en/safeguarding-your-research/general-information-research-security/international-research-security-resources/g7-common-values-and-principles-research-security-and-research-integrity (accessed 21 January 2025).

41 OECD, 2022. Integrity and Security in the Global Research Ecosystem. See https://www.oecd.org/en/publications/integrity-and-security-in-the-global-research-ecosystem_1c416f43-en.html (accessed 21 January 2025); See also https://stip.oecd.org/stip/research-security-portal (accessed 23 January 2025)

42 Wang, J., Frietsch, R., Neuhäusler, P., Hooi, R., 2024. International Collaboration Leading to High Citations: Global Impact or Home Country Effect? See https://www.sciencedirect.com/science/article/abs/pii/S1751157724000786?via%3Dihub (accessed 21 January 2025).

43 For example, the NSF's Research on Research Security Programme (RoRS). See https://new.nsf.gov/research-security (accessed 24 January 2025).

44 The Arctic States include Canada, Demark, Finland, Iceland, Norway, Sweden, Russia, and the U.S.A. The Arctic Council also includes representation by Indigenous groups.

45 Gibney, E., 2024. CERN prepares to expel Russian scientists – but won't completely cut ties. See https://www.nature.com/articles/d41586-024-02982-6 (accessed 21 January 2025).

46 The growth of the Foreign Ministries Science & Technology Advice Network (FMSTAN) from a handful of science advisers in foreign ministries in 2016 to over 30 today provides some indication of this. International Network for Government Science Advice (INGSA), 2023. Foreign Ministries Science & Technology Advice Network (FMSTAN). See https://ingsa.org/divisions/fmstan/ (accessed 21 January 2025).

47 Nature, 2024. Advising governments about science is essential but difficult. So train people to do it. See https://www.nature.com/articles/d41586-024-03910-4 (accessed 21 January 2025).

48 Pearson, H., 2024. Science could solve some of the world's biggest problems. Why aren't governments using it? See https://www.nature.com/articles/d41586-024-03906-0 (accessed 21 January 2025).

49 Nogrady, B., 2021. 'I hope you die': how the COVID pandemic unleashed attacks on scientists. See https://www.nature.com/articles/d41586-021-02741-x (accessed 21 January 2025).

50 Dolan, B. M., 2012. Science and Technology Agreements as Tools for Science Diplomacy: A U.S. Case Study. See https://www.sciencediplomacy.org/sites/default/files/science_and_technology_agreements_as_tools_for_science_diplomacy_science__diplomacy.pdf (accessed 21 January 2025).

51 Hammond, J., 2023. Science and Sanctions: Lessons Learned from Twelve Years of Collaboration with the DPRK (North Korea). See https://www.sciencediplomacy.org/article/2023/science-and-sanctions-lessons-learned-twelve-years-collaboration-dprk-north-korea (accessed 21 January 2025).

52 Gutmann. J., Neuenkirch, M., Neumeier, F., 2023. The economic effects of international sanctions: An event study. See https://www.sciencedirect.com/science/article/abs/pii/S0147596723000525 (accessed 21 January 2025).

53 Clarke, L., Craig, C., Mesfin, M. N., Wang, T., C., 2018. Beyond the Political Moment: Strengthening Science-Trade Ties, See https://www.sciencediplomacy.org/editorial/2018/beyond-political-moment-strengthening-science-trade-ties (accessed 21 January 2025).

54 Engler, 2023. The EU and U.S. diverge on AI regulation: A transatlantic comparison and steps to alignment. See https://www.brookings.edu/articles/the-eu-and-us-diverge-on-ai-regulation-a-transatlantic-comparison-and-steps-to-alignment/#:~:text=The%20EU%20and%20U.S.%20are%20taking%20distinct%20regulatory%20approaches%20to,rules%20for%20these%20AI%20applications (accessed 21 January 2025).

55 Buntz, B., 2024. Top 30 R&D spending leaders of 2023: Big Tech firms spending hit new heights. See https://www.rdworldonline.com/top-30-rd-spending-leaders-2023-big-tech-firms-hit-new-heights/ (accessed January 21 2025).

56 See further: Kolker J., 2018. A Diplomat's Perspective on Use of Science and Evidence in Implementing PEPFAR. See https://www.sciencediplomacy.org/article/2018/diplomats-perspective-use-science-and-evidence-in-implementing-pepfar (accessed 21 January 2025).

57 Dufour, P., 2024. Navigating Science Diplomacy Futures. See https://www.sciencediplomacy.org/perspective/2024/navigating-science-diplomacy-futures (accessed 21 January 2025).

58 See for example Dzau, V., J., McNutt, M., 2020, NAS and NAM Presidents Alarmed By Political Interference in Science Amid Pandemic. See https://www.nationalacademies.org/news/2020/09/nas-and-nam-presidents-alarmed-by-political-interference-in-science-amid-pandemic (accessed 21 January 2025)

59 Gluckman, P., 2016. Science Advice to Governments: An Emerging Dimension of Science Diplomacy. See http://www.sciencediplomacy.org/article/2016/science-advice-governments (accessed 21 January 2025).

60 Pielke, R., 2003. The Honest Broker. United Kingdom: Cambridge University Press.

61 Burnett, K., 2021. A China-UK dialogue on artificial intelligence. See https://royalsociety.org/blog/2021/04/a-china-uk-dialogue-on-artificial-intelligence/ (accessed 21 January 2021).

62 The American Association for the Advancement of Science (AAAS) and the Royal Society, 2010. New Frontiers in Science Diplomacy. See https://royalsociety.org/news-resources/publications/2010/new-frontiers-science-diplomacy/ (accessed 21 January 2025).

63 Brimmer, E., 2023. Changing Geopolitics in the Arctic. See https://www.cfr.org/report/changing-geopolitics-arctic-0 (accessed 21 January 2025).

64 In contrast, the Antarctic is a continent surrounded by oceans with no permanent human population, and home to a few thousand scientists and researchers at any one time. It is unambiguously a shared international space, which influences the type of activity that is considered or claimed to be acceptable, although this too is increasingly contested. See further: Lennon, E., 2008. A Tale of Two Poles: A Comparative Look At The Legal Regimes in The Arctic And The Antarctic See: https://digitalcommons.wcl.american.edu/cgi/viewcontent.cgi?article=1066&context=sdlp (accessed 21 January 2025) and Gehrke, C., Wood-Donnelly, C., 2024. Science Diplomacy Challenges at the Poles. See https://www.sciencediplomacy.org/perspective/2024/science-diplomacy-challenges-poles (accessed 21 January 2025).

65 See https://arctic-council.org/ (accessed 21 January 2025).

66 For example, through the drafting of the 1991 Arctic Environmental Protection Strategy (“AEPS”). See https://library.arcticportal.org/1542/1/artic_environment.pdf (accessed 21 January 2025).

67 Lennon, E., 2008. A Tale of Two Poles: A Comparative Look At The Legal Regimes in The Arctic And The Antarctic See: https://digitalcommons.wcl.american.edu/cgi/viewcontent.cgi?article=1066&context=sdlp (accessed 21 January 2025).

68 United Nations, 1982. United Nations Convention on the Law of the Sea (UNCLOS). See https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (accessed 21 January 2025).

69 See e.g., Bermann. M., Østhagen, A., Svendsen. O., 2023. Arctic Geopolitics: The Svalbard Archipelago. See https://www.csis.org/analysis/arctic-geopolitics-svalbard-archipelago (accessed 21 January 2025).

70 To international observers – for those living in the Arctic, and in particular Indigenous peoples, the inconsistency of legal regimes and their enforcement has been keenly felt. See further: Koubrak, O., MacLeod, S., Seck, S., Sharapova, A., 2022. Indigenous Rights and Interests in a Changing Arctic Ocean: Canadian and Russian Experiences and Challenges. See https://arcticreview.no/index.php/arctic/article/view/3264/6574 (accessed 21 January 2025).

71 Other examples of such spaces include the Antarctic, outer space, and the deep ocean.

72 See e.g., Banks, J. P., Ebinger, C., Schackmann, A., 2014. Offshore Oil and Gas Governance in the Arctic: A Leadership Role for the U.S. See: https://www.brookings.edu/wp-content/uploads/2016/07/Offshore-Oil-and-Gas-Governance-text-revised.pdf (accessed 21 January 2025).

73 United Nations, 1982. United Nations Convention on the Law of the Sea (UNCLOS). See https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (accessed 21 January 2025).

74 Łuszczuk, M., Padrtova, B., Szczerbowicz,, W., 2020. Political dimension of Arctic research. See https://www.sciencedirect.com/science/article/pii/S0078323420300294?ref=pdf_download&fr=RR-2&rr=90616cf87825654b (accessed 21 January 2025).

75 Banks, J. P., Ebinger, C., Schackmann, A., 2014. Offshore Oil and Gas Governance in the Arctic: A Leadership Role for the U.S. See: https://www.brookings.edu/wp-content/uploads/2016/07/Offshore-Oil-and-Gas-Governance-text-revised.pdf (accessed 21 January 2025).

76 Krysiek, T. F., Yenikeyeff, S. M., 2007. The Battle for the Next Energy Frontier: The Russian Polar Expedition and the Future of Arctic Hydrocarbons. See https://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/01/Aug2007-TheBattleforthenextenergyfrontier-ShamilYenikeyeff-and-TimothyFentonKrysiek.pdf (accessed 21 January 2025).

77 Most notably the 2022 and 2021 cable disruption incidents within Norwegian Arctic waters near Svalbard, a precursor to the similar 2022 Nord Strom incident in the Baltic. Center for Strategic &International Studies, 2022. Security Implications of Nord Stream Sabotage. See https://www.csis.org/analysis/security-implications-nord-stream-sabotage (accessed 21 January 2025).

78 Bermann. M., Østhagen, A., Svendsen. O., 2023. Arctic Geopolitics: The Svalbard Archipelago. See https://www.csis.org/analysis/arctic-geopolitics-svalbard-archipelago (accessed 21 January 2025).

79 Chuffart, R., Cooper, A. M., Wood-Donnelly, C., Seddon, L., 2023. Old Sea, New Ice: sea ice geoengineering and indigenous rights in Arctic Ocean governance. See https://doi.org/10.1080/2154896X.2023.2269688 (accessed 21 January 2025).

80 Dawes, J., Salt, K., Smith, C., 2024. Achieving Research Security While Pursuing Science Diplomacy: Considering Intentionality. See https://www.sciencediplomacy.org/perspective/2024/achieving-research-security-while-pursuing-science-diplomacy-considering (accessed 21 January 2025).

81 For more on the role of science within the East India Company., see Armies of the East India Co. | National Army Museum (accessed 4 February 2025)

82 Congressional Budget Office (2021). Research and Development in the Pharmaceutical Industry.

83 See "OECD Data Explorer • Main Science and Technology Indicators (MSTI database). Between 1991 and 2023, business-sector investment in China jumped from 39% to 77%. Within the other countries listed, business-sector investment in R&D has increased approximately 10%-15% within the past 40 years. (accessed 4 Feb 2025).

84 Statista (2025). Ranking of the companies with the highest spending on research and development worldwide in 2022. See https://www.statista.com/statistics/265645/ranking-of-the-20-companies-with-the-highest-spending-on-research-and-development/ (accessed 4 February 2025).

85 Here meaning 'having power of authority that is greater than that of single countries'. See https://dictionary.cambridge.org/dictionary/english/supranational (accessed 4 February 2025).

86 Shearer, E., Davies, M., Lawrence, M., (2024). The role of public compute. Ada Lovelace Institute blog. See https://www.adalovelaceinstitute.org/blog/the-role-of-public-compute/ (accessed 4 February 2025).

87 Hayward, T., 2021. Calculated Consequences: The Case of Alibaba. See https://www.csis.org/blogs/new-perspectives-asia/calculated-consequences-case-alibaba (accessed 24 January 2025).

88 Montgomery, K. Wiggins, I., 2024. The Special Issue: Science Diplomacy – 15 Years On. See https://www.sciencediplomacy.org/editorial/2024/special-issue-science-diplomacy-15-years (accessed 21 January 2025).

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