gesda | Geneva Science and Diplomacy Anticipator

Anticipatory Science Diplomacy

A framework for global action

Geneva • July • 2025

Lead author Marga Gual Soler

Contributors Marilyne Andersen, Stéphane Decoutère, Gérard Escher, Sandro Giuliani, Daria Robinson, Martin Müller, Marieke Hood, Alice Hazelton, Marianne Schörling, Sophie Gilbert, Manuel Gustavo Isaac, Federica Du Pasquier, Mira Wolf-Bauwens, Catherine Lefebvre, Ian Horuzhiy

Editorial lead Marianne Schörling

Editor Sumit Paul-Choudhury for Scientification LLP

Design International Media Communication Sàrl

Acknowledgements GESDA thanks Marie Sophie Müller, Lene Topp and Claudia Alarcón for their early contributions to this work.

How to cite this report Geneva Science and Diplomacy Anticipator (GESDA). *Anticipatory Science Diplomacy: A Framework for Global Action.* Geneva: Geneva Science and Diplomacy Anticipator Foundation, 2025.

gesda

The Geneva Science and Diplomacy Anticipator Foundation

The Geneva Science and Diplomacy Anticipator (GESDA) is a private Swiss foundation, established in 2019 in Geneva with a global reach. GESDA's mission is to anticipate emerging scientific discoveries at a 5, 10, 25 years time horizons and translate their early uses into benefits for society. Through anticipatory science diplomacy and public-private partnerships, GESDA contributes to strengthening multilateral collaboration and to reinforcing the role of Geneva and Switzerland as a hub for diplomacy and innovation.
http://gesda.global

Foreword

Our world is increasingly defined by the intersection of two accelerating forces.

On one hand, science and technology are advancing at unprecedented speed, producing breakthroughs —from CRISPR gene editing techniques to generative AI tools like ChatGPT— that are reshaping every aspect of human life. Yet these breakthroughs often unfold faster than our collective ability to understand, govern, or even imagine their implications.

On the other hand, the world is becoming increasingly fragmented —geopolitically, economically, and socially— undermining the very multilateral mechanisms designed to channel scientific progress for the common good. This dual acceleration risks leaving both global cooperation and scientific opportunity behind.

In this context, I have long argued that knowledge must be recognised as a fundamental freedom that must circulate openly and equitably across borders. But freedom of knowledge is not a given: it must be actively built. This report by GESDA offers a compelling vision for how we can anticipate the future of science and shape the global governance needed to ensure it benefits humanity as a whole.

By empowering current and future leaders with the mindsets and tools to steward knowledge responsibly, we can bridge divides, prevent new conflicts, and reimagine leadership for an age when the future is arriving faster than ever.

— Enrico Letta
GESDA Board Member
Chair of the Diplomacy Forum

Contents

Executive summary

Scientific and technological breakthroughs — from artificial intelligence and quantum computing to synthetic biology and climate engineering — are reshaping who we are as humans, how we live together, and how we relate to our planet.

These advances have elevated science as a core currency in international affairs, influencing prosperity, sovereignty, and security globally. However, our existing diplomatic and multilateral mechanisms are struggling to keep pace with the speed, scale, and complexity of this transformation

At the same time, intensifying geopolitical rivalries and the arrival of new, non-state actors are reshaping global governance. Expertise and resources are being distributed —and sometimes hoarded— across multiple poles, throwing the scientific ideals of borderless knowledge-sharing and cooperation into doubt. The demands of open science and national security are clashing, amid proliferating planetary crises and heightened military conflicts.

These dynamics threaten the foundations of the rules-based international order, which has for decades provided the shared norms and multilateral frameworks that underpin transnational solutions to cross-boundary challenges.

Over the past 15 years, science diplomacy has emerged as a key tool in addressing global challenges, grounded in the idealistic promise of science as a universal language capable of transcending political and ideological divides.

Science diplomacy comes in several forms, including the use of scientific advice to inform negotiations and shape agreements; the creation of international scientific collaborations to forge cooperation outside the constraints of conventional politics; and the joint enterprise of many individual nations to solve supranational challenges. Science diplomacy has proven its value repeatedly in past decades, but if it is to remain relevant in today's fragmented context, the way it is practiced will have to evolve.

Anticipatory Science Diplomacy: a new approach by GESDA

This paper introduces **Anticipatory Science Diplomacy** — a new approach pioneered by the Geneva Science and Diplomacy Anticipator (GESDA). Anticipatory science diplomacy aims to strengthen and revitalise the multilateral system by enabling the scientific, diplomatic, business and citizen communities to proactively govern and deploy scientific advances together for the benefit of humanity, well before they become sources of disruption, instability or inequality.

The framework is based on four pillars:

Science anticipation. Identify and scope out the major scientific advances with the highest potential to reshape humanity and the planet, as GESDA does for five-, ten- and 25-year timescales.[1]

Honest brokering. Convene and connect diverse communities to discuss and align early on the implications and applications of emerging science, thus expanding the scope for action in the present.[2,3]

Global action. Prototype early multilateral solutions and frameworks that maximise the benefits of future science advances and minimise their potential risks.

Capacity building. Empower communities and leaders with the tools to anticipate, understand, harness and govern emerging science for the benefit of humanity.

The GESDA Framework on Anticipatory Science Diplomacy

Science anticipation

Identify and scope out the major scientific advances with the highest potential to reshape humanity and the planet, as GESDA does for five-, ten- and 25-year timescales.

Honest brokering

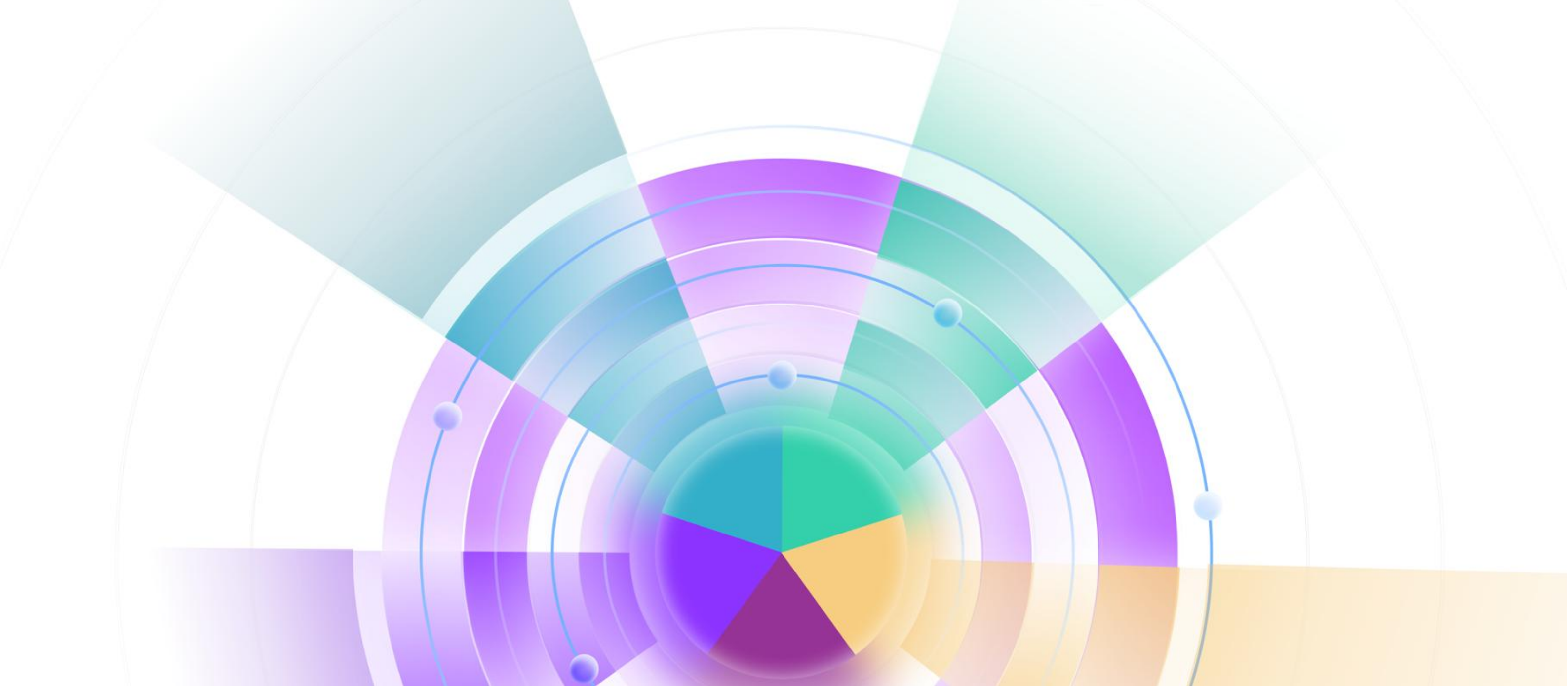
Convene and connect diverse communities to discuss and align early on the implications and applications of emerging science, thus expanding the scope for action in the present.

Global action

Prototype early multilateral solutions and frameworks that maximise the benefits of future science advances and minimise their potential risks.

Capacity building

Empower communities and leaders with the tools to anticipate, understand, harness and govern emerging science for the benefit of humanity.



This anticipatory approach fills a critical gap between knowledge and action, allowing coalitions of the willing to move forward when multilateral consensus is elusive. It has already been put into practice, with GESDA prototyping initiatives and governance models for breakthrough technologies long before they reach mainstream deployment.

GESDA has incubated the **Open Quantum Institute**, a pioneering initiative dedicated to ensuring that the fruits of quantum computing become widely accessible; contributed to Switzerland's mandate at the United Nations Security Council; and launched a Global Curriculum for Anticipatory Leadership to build capacities worldwide.

By anchoring its work in the global governance hub of International Geneva, GESDA bridges local and global science diplomacy ecosystems, while its tools and methodologies are increasingly adopted in fields such as neurotechnology, biosecurity, climate and quantum technologies.

In doing so, GESDA combines its science anticipation methodology with elements from science diplomacy and anticipatory governance to provide concrete blueprints and initiatives, based on public-private partnerships, to enhance the legitimacy and effectiveness of the multilateral system.

Anticipatory Leadership for a world accelerated by science and technology

Anticipation is a key leadership competency for addressing opportunities and challenges posed by scientific breakthroughs, navigating the complexities and polarities of a rapidly changing global landscape and helping the world benefit faster and more effectively from advances in science and technology.

To that end, GESDA has developed a new leadership development approach: **Anticipatory Leadership,** a mindset and method inspired by science itself, grounded in scientific literacy, openness, international collaboration and continuous adaptation.

The Anticipatory Leadership framework begins with the ***foundational knowledge*** needed to understand relevant disciplines, sectors and mindsets, then providing a grounding in ***science anticipation*** to ensure that leaders are aware of areas of significant scientific development, based on the GESDA Science Breakthrough Radar.® Applying ***science diplomacy lenses*** helps to understand the links between scientific advances and their societal implications and applications. Finally, it develops the ***capacity to act*** through experiential learning, simulation-based training, and rapid prototyping of solutions.

In this way, Anticipatory Leadership infuses principles from science into the public and private sectors and society at large that are essential to navigate our changing world. The tenets of the scientific method offer immense value for shaping diplomatic frameworks that can evolve with the pace of innovation, preparing leaders today to govern disruption tomorrow.

> Anticipation is the engine for science diplomacy to remain fit for purpose, open and inclusive for the future.

In an era of deep geopolitical divides, science remains one of the last universal bridges —a domain where shared progress is still possible. Anticipation can unlock and accelerate the potential of science and technology to benefit all of humanity, offering new modes of engagement where traditional diplomacies stall. In this way, GESDA contributes not only to bridging the gap between science and diplomacy, but also to operationalizing anticipation as a core diplomatic competency.

GESDA's model offers a blueprint for a new kind of science diplomacy: one that anticipates rather than reacts, embraces complexity rather than avoids it, and extends to everyone with a stake in our shared future.

1. A brief history of science diplomacy

1.1 From the Silk Road to spaceflight

Science diplomacy, broadly speaking, is the use of scientific collaborations and knowledge exchange to build bridges between nations. Although the term is relatively new, having risen to prominence in the early 21st century, science diplomacy has in fact been practised for centuries.

For example, scholars and scientists travelled along the ancient Silk Road trade routes between courts, sharing advances in astronomy, mathematics, and medicine, thereby dispersing scientific knowledge across Asia, the Middle East and ultimately Europe. Chinese innovations like papermaking and compass technology migrated West, while Greek and Arabic astronomical and mathematical knowledge found its way to other empires. Such transfers and exchanges helped to foster engagement between disparate civilizations through the common language of science.[4]

Scientific knowledge occasionally influenced diplomacy and treaty-making even in pre-20th-century history. For example, geographers and astronomers played a role in delineating borders by providing surveys and maps that all sides could trust. And science could also provide the foundations for standards that spanned different societies, thus facilitating commerce: for example, the Metre Convention of 1875 codified a diplomatic consensus to adopt consistent and verifiable standards of measurement.[5]

The 20th century saw science diplomacy expand and institutionalise, as science itself assumed critical strategic importance both in waging war and keeping peace. While scientific breakthroughs were exploited for national advantage during times of global conflict and geopolitical rivalry, scientific collaborations were used to promote cooperation and rebuild trust at other times and in other contexts. For example, the League of Nations Health Organization, a precursor to the World Health Organization, was established in 1921 after the “Spanish Flu” pandemic highlighted the urgent need for international cooperation in public health.[6]

The role of science diplomacy is also evident in the course of one of the 20th century's key technologies — nuclear energy. The atomic bomb was the product of intensely protectionist and competitive scientific research during the closing stages of World War Two, but in its aftermath nuclear science assumed a central role in diplomacy.

In 1946, the newly formed United Nations created the UN Atomic Energy Commission to control nuclear weapons — one of the first major science—driven diplomatic initiatives. Although that commission failed amid growing East-West tensions, the US launched the Atoms for Peace programme in the 1950s, proposing international cooperation in peaceful nuclear research. This initiative, marked by a high-profile 1955 conference in Geneva, laid the groundwork for the International Atomic Energy Agency (IAEA) in 1957 to promote nuclear cooperation under safeguards.[7] The IAEA became an early example of a global scientific institution explicitly aimed at balancing scientific advancement with diplomatic oversight of technology.

The latter half of the 20th century also saw the creation of large-scale scientific organisations and agreements which embodied multilateral science diplomacy, with UNESCO (1945) and the World Health Organization (WHO, 1948) being founded on the premise that sharing scientific knowledge would foster peace.

In 1954, 12 European countries founded the European Organization for Nuclear Research (CERN), using collaboration in high-energy physics to help reconcile nations after World War Two. CERN’s model of open scientific cooperation, today involving over 25 member states and many associate members, became a flagship example of science diplomacy, hosting early contacts between scientists from adversarial countries, such as those between German and Israeli physicists, and demonstrating that shared scientific goals could overcome political divisions.[8]

Other scientific fields also lent themselves to diplomatic efforts. The International Geophysical Year (IGY) of 1957-1958, for example, was a major international project that fostered science diplomacy during the Cold War. It involved 67 countries studying Earth and its environment, with a focus on the polar regions and outer space. The success of the IGY in promoting international scientific collaboration, even amidst political tensions, led to the establishment of the Antarctic Treaty in 1959.[9]

During the Cold War, science diplomacy became a critical avenue for communication between East and West. Both blocs invested in scientific exchanges to maintain dialogue and reduce hostilities when official diplomatic channels were strained. In 1961 the United States and Japan signed a science and technology cooperation agreement intended to help normalise their postwar relationship.

Throughout the Cold War, the US and U.S.S.R. cooperated on space exploration despite their rivalry — a notable instance being the 1975 Apollo–Soyuz joint spaceflight, where American and Soviet spacecraft docked together in orbit in a gesture of scientific camaraderie amid détente. Scientific and technical cooperation also extended to the rest of the world, as both the US and USSR offered training, technology, and research projects to non-aligned developing countries as a form of influence and goodwill, subtle intelligence gathering or soft-power projection.[10]

Non-governmental dialogues flourished: the Pugwash Conferences on Science and World Affairs, initiated in 1957 by scientists alarmed by nuclear weapons, brought Eastern and Western scientists together to discuss arms control and conflict resolution. Pugwash and similar informal diplomatic initiatives by non-state actors, including groups of scientists and citizens (so-called Track II initiatives), demonstrated science's power to keep communication alive and even influenced agreements like the 1963 Partial Nuclear Test Ban.[11]

Thus, even as political tensions divided the globe, a parallel international community of scientists helped build trust and contributed to eventual diplomatic breakthroughs: for instance, scientific exchanges were instrumental in the 1970s rapprochement between the US and China,[12] and later in the normalisation of US-Cuba diplomatic relations in 2015.[13] Establishing scientific cooperation agreements is often the first approach countries undertake when trying to improve or restart their official relations.[14]

The impact of science diplomacy is evident in the way global challenges are managed, with the integration of scientific expertise and networks into decision-making enabling countries to achieve more robust and evidence-informed agreements.

> By the end of the 20th century, nearly every major international treaty in arms control, environmental protection or public health involved scientific expert groups informing negotiators — a testament to how deeply science has been woven into diplomacy.

Ozone depletion, epidemics, ocean protection and biodiversity loss have seen progress largely through international alliances of scientists and diplomats working hand in hand.

Security agreements often rely on scientific verification methods — such as seismic networks to detect nuclear tests— developed and operated through international scientific partnerships (see Box 1, What has science diplomacy achieved?).

What has science diplomacy achieved?

Science diplomacy has been instrumental in shaping international cooperation and global governance. Many foundational treaties and institutions that address global challenges, such as climate change, health, and international security are underpinned by scientific collaboration and expertise. Some examples include:

The Antarctic Treaty (1959). Signed at the height of the Cold War, this landmark agreement reserved Antarctica exclusively for peaceful scientific research and effectively made science the basis for the governance of an entire continent, setting a precedent for cooperation even among geopolitical rivals.[15]

The Montreal Protocol (1987). A treaty on substances that deplete the ozone layer, it remains the only universally ratified environmental agreement. The protocol brought together science, diplomacy, and industry to phase out ozone-depleting and climate-warming substances.[16]

The Intergovernmental Panel on Climate Change (IPCC, 1988). The IPCC scientific assessments — particularly the Physical Science Basis reports — have been crucial in aligning the diplomatic community around the reality and urgency of climate change. While the current pace of climate action remains insufficient, the IPCC's role in forging consensus mechanisms like the Paris Agreement remains a cornerstone achievement.[17]

The Eradication of Smallpox (1980). Despite Cold War tensions, the US and Soviet Union collaborated through the World Health Organization, contributing scientific resources, public health expertise, and surveillance tools in a feat that led to the first human disease to be eliminated globally through universal vaccination, prevention and containment.[18]

Source: Marga Gual Soler, Antarctica.

The United Nations Convention on the Law of the Sea (UNCLOS, 1982). Exemplified how scientific knowledge such as oceanographic research, mapping of the seabed and marine ecosystem data was central to negotiating maritime boundaries and conserving ocean biodiversity. It created frameworks for marine scientific research, sustainable fisheries, and deep-sea mining governance.[19]

The Chemical Weapons Convention (CWC, 1993). The CWC is a science-based arms-control treaty that prohibits the development, production, and use of chemical weapons. It includes rigorous verification protocols relying on scientific methods for detection, inspection, and destruction of stockpiles. The CWC was the world's first multilateral disarmament agreement to provide for the elimination of an entire category of weapons of mass destruction and has led to the elimination of over 99 per cent of declared chemical weapons stockpiles globally.[20]

Box 1: What has science diplomacy achieved?

1.2 International Geneva: a hub for science diplomacy

Much of what we now call science diplomacy has deep roots in International Geneva, dating from long before the term was coined. Science has historically played a central role in Swiss diplomacy, particularly in Geneva, a **global hub of multilateral governance**. As the host of the UN Office at Geneva, Switzerland supports 184 diplomatic representations, 43 international organisations, over 2000 multinational companies[21] and 750 NGOs[22] working across domains as diverse as peacebuilding, disarmament, human rights, humanitarian law, trade, sustainability, health, telecommunications, climate, intellectual property, and standards.[23]

Geneva has consistently fostered **cross-border scientific collaboration** and institutional innovation. The city's legacy began with the creation of the University of Geneva in 1559, followed by key institutions such as the International Committee of the Red Cross (ICRC, 1863) and the International Telecommunication Union (ITU, 1865).

The Graduate Institute of International and Development Studies (1927) has long trained diplomats, scholars and policymakers at the League of Nations and, subsequently, the United Nations and its member states. Geneva was chosen to host CERN due in part to Switzerland's political neutrality and strong tradition in science and diplomacy. CERN has thus fostered major breakthroughs including the invention of the World Wide Web and the discovery of the Higgs boson. Geneva's scientific excellence is also reflected in its Nobel prizewinners in astrophysics and medicine, and Fields medallists in mathematics.

Today, Geneva hosts a **rich constellation of organisations and platforms** that bridge science and diplomacy. These include the World Economic Forum, the Beyond Lab at the UN Office at Geneva and initiatives such as Building Bridges for sustainable finance, the Geneva Centre for Security Policy and the Geneva Science-Policy Interface.

Geneva-based organisations working at the interface of science and multilateral diplomacy include the World Health Organization, the World Meteorological Organization, co-host of the IPPC, the International Organization for Standardization, and humanitarian initiatives such as EPFL EssentialTech Centre which links technology to sustainable development and humanitarian response in partnership with ICRC. Digital and cyber governance is represented through DiploFoundation, the CyberPeace Institute, the Geneva Internet Platform, and ITU's AI for Good.

Guided by the United Nations 2030 Agenda for Sustainable Development and the Universal Human Right to Science,[24] Geneva continues to champion **science-informed solutions for global challenges**, reflecting Switzerland's longstanding commitment to the rule of law, peace, neutrality, and human rights. Notably, Switzerland was the first country to appoint a Special Representative for Science Diplomacy with the rank of Ambassador.[25]

The latest expression of this commitment came in 2019 with the establishment by the Swiss and Geneva governments of the Geneva Science and Diplomacy Anticipator (GESDA). GESDA's mission is to anticipate emerging scientific discoveries at a 5-, 10-, and 25- year time horizons and translate their early applications into benefits for society through public-private partnerships— thus pioneering a model for integrating the future of science in the global diplomatic agenda.

Source: Marc Bader, Geneva Science Diplomacy Week 2025

2. The 21st-century evolution

2.1 More formal approaches emerge

As science diplomacy grew in prominence in the early part of this century, it became apparent that the concept should be defined more formally. As such, in 2010 the UK's Royal Society and the American Association for the Advancement of Science (AAAS) published the landmark report *New Frontiers in Science Diplomacy*,[26] which set out three distinct roles that science can play in diplomacy:

— informing negotiations with scientific evidence ("**science in diplomacy**");

— serving as a form of "soft power" that sustains ties between nations when these are under political strain ("**science for diplomacy**"); and

— helping nations join forces to address issues that no single country can solve ("**diplomacy for science**").

This conceptual model quickly gained traction and catalysed the global uptake of science diplomacy as a formalised practice, spurring on a surge in recognition, strategic development, and institutional investments. Governments and international bodies began crafting explicit strategies, launching national and regional science diplomacy frameworks and strengthening their scientific and technological advisory capacities.

Measures taken included the appointment of chief science advisers to heads of government or foreign ministries,[27,28] expanding the roles of science and technology ambassadors, attachés and counsellors, and introducing new diplomatic mechanisms focused on scientific engagement.[29] These efforts were accompanied by the establishment of dedicated science diplomacy centres and training programmes across different regions,[30,31] science diplomacy funds and fellowships,[32] and networking events and capacity building mechanisms.[33]

At the multilateral level, the European Union was the first region to devise a science diplomacy strategy in 2016,[34] and advisory bodies have since emerged within major governance forums, such as the G7, G20, and BRICS.

Most recently, the United Nations established a new Secretary-General's Scientific Advisory Board (SAB), with a membership composed of both governmental and non-governmental actors.[35] The SAB operates under the Science and Diplomacy Joint Programme to strengthen the UN's use of science and technology in its policies, programmes and key decision-making processes.[36] In March 2025, UNESCO hosted the first ever Ministerial-level dialogue on science diplomacy at its Paris headquarters.[37]

While the post-2010 decade saw science diplomacy become a robust and widely recognised pillar of international relations, expanding rapidly in scale, thematic scope, and stakeholder diversity, it also exposed several conceptual and practical limitations.

First, the idealistic promise of science as a "universal language" transcending political and ideological divides — one that can help to avert conflicts and promote peace and international cooperation — has given way to a realpolitik view, with scientific development and technological controls becoming much more integrated with geopolitical and geoeconomic priorities.

Second, scientific evidence alone does not automatically translate into political traction, decisions or action, despite the close association of science diplomacy with traditional scientific advisory mechanisms. This is especially true when policy choices are shaped by broader political, economic, and societal factors.

The COVID-19 pandemic, for example, served as a "stress test" of science diplomacy.[38] On the one hand, there was an unprecedented international collaboration to sequence the virus genome and develop multiple vaccines in record time, several of them using novel mRNA technology. On the other, scientific advice was often undermined by adversarial politicians and misinformation. Despite considerable advance warning, global governance structures proved weak when it came to ensuring transparent reporting of the disease's spread, leading to suspicion about the virus' origins and effects. There was also little capacity to ensure equitable distribution of medical equipment and pharmaceuticals, leading to "vaccine nationalism" and disproportionate disease tolls. The framing of science diplomacy as a vehicle of "soft power" gave way as it became entangled with "hard power" dynamics.

Third, the growing popularity of science diplomacy has led to a dilution of its meaning. Its transdisciplinary nature made it attractive across academic, policy, and diplomatic communities, but also prone to being used as a catch-all label for any initiative involving science.[39] As a result, many cross-border scientific collaborations have been labelled as science diplomacy, even when they lack strategic intent or demonstrable impact on foreign policy or international governance. This proliferation of uses risks obscuring the distinction between scientific cooperation and diplomacy, underscoring the need for clearer frameworks to ensure science diplomacy remains purpose-driven, coherent, and impactful.

2.2 A challenging and changing landscape

The global landscape in which science diplomacy operates has transformed dramatically in recent years. Relative geopolitical stability, democratic expansion, and a cooperative spirit of multilateralism enabled the rapid diffusion of science diplomacy as a recognised and institutionalized practice. But today, fifteen years after the landmark *New Frontiers in Science Diplomacy* report was published, that enabling environment has been significantly eroded, due to several interlinked paradigm shifts:

Science and technology acceleration
Advances in science and technology — from artificial intelligence and quantum computing to synthetic biology and climate engineering — now touch every aspect of life, driving social and economic transformation and reshaping international affairs faster than governance mechanisms can adapt. AI is transforming diplomacy itself — through applications such as computational diplomacy, real-time negotiation analytics, big data-driven foreign policy modelling and predictive peacekeeping.[40]

These breakthroughs have elevated science and innovation from benign instruments of cooperation to geopolitical assets that redefine sovereignty, security, and global influence. As science becomes a driver of political and military power, the boundary between technological and diplomatic domains is increasingly porous.

Geopolitical and geoeconomic fragmentation
The post-Cold War unipolar moment has been replaced by a contested multipolar environment. Resurgent power rivalries, armed conflicts, and domestic polarisation — exacerbated by disinformation and misinformation — are undermining the cooperative foundations required for science-informed governance and action.

The virtues of globalisation, once a standard for global development, have been called into question, with consequences for growth, investment, and international value chains both in advanced and emerging economies — even though citizens, states and international bodies remain interconnected by the internet and real-time information. As a result, consensus is eroding when it comes to challenges such as international security, trade, climate change, biodiversity loss, and global health threats — even as the urgency for coordinated responses grows.

Commercialisation and militarisation of the global commons
Shared resource management is becoming more complex and contentious. Previously governed by scientific cooperation, global

commons such as the oceans, polar regions, and outer space are now arenas of strategic competition. Private actors and state-backed ventures are vying for influence in these domains —whether through seabed mining, polar shipping routes, satellite constellations or space mining. The erosion of cooperation frameworks like the Antarctic Treaty or strain on bodies like the Arctic Council illustrate how science-based multilateral governance can falter when sovereignty and resource claims take precedence.

Tensions between open science and security
The historic ethos of open international scientific collaboration is now under pressure from rising concerns over research security, IP theft, and dual-use risks. Governments are tightening controls on technology transfer, export regimes and the migration of talent, in efforts to defend national sovereignty and competitiveness. Dual-use research, where the same innovations can serve both civilian and military purposes, poses particularly pointed ethical and strategic dilemmas in fields such as biotechnology, AI, quantum and cybersecurity.

The growing role of private actors in shaping international affairs
As the private sector has become the dominant contributor to research and innovation, technology giants, philanthropic foundations, and deep-tech startups now exert influence over science, innovation, international norms, budgets and political agendas at a pace far surpassing that of traditional state actors.[41] Therefore, many countries have started appointing representatives to innovation hubs such as Silicon Valley or the Pearl River Delta around Shenzhen, Guangzhou and Hong-Kong —a novel diplomatic function first pioneered by Denmark in 2017.[42] In turn, technology companies have begun practicing their own forms of statecraft, establishing offices in key multilateral hubs such as New York, Geneva or Brussels[43] (see Box 2, The Rise of Tech Diplomacy).

These new realities mean that there are increasingly areas of tension that involve science and technology. Traditionally open and liberal countries and regions have begun shifting their stances —for example, the EU has suspended the involvement of Russian scientists in EU-funded programmes following the invasion of Ukraine. Russia has reciprocated: the International Space Station, a symbol of science diplomacy, may be jeopardised if Russia withdraws from it.[44]

Negotiations over the location of key "big science" projects, such as particle accelerators, are becoming potential sources of conflict and competition: science diplomacy is being used to leverage national and regional power, calling into question the idealized vision of science diplomacy as inherently at the service of peace.[45]

While diplomacy has historically managed well the risks posed by new technologies, such as nuclear weapons, today’s pace of innovation across a wide range of scientific fields and actors poses unprecedented challenges.

With private companies wielding significant control over critical technologies, exemplified by AI development becoming increasingly monopolised by a few major corporations, these shifts spark new questions around accountability, equity, and governance — particularly when the development of cutting-edge technologies resides largely outside the oversight of states and international organisations.

While science diplomacy still has a role to play, it must now evolve to suit the demands of the 21st century.

The Rise of Tech Diplomacy

Biomedicine: Google DeepMind developed AlphaFold, which revolutionized protein folding research — an area historically dominated by public-sector biology labs. Deep-tech companies like Illumina, 23andMe, Emotiv and Grail have commercialised genomic testing, neurotechnology devices and early cancer detection tests, marketing directly to consumers and shaping new markets before government guidelines could catch up.

Artificial intelligence: OpenAI (initially a nonprofit) released ChatGPT, backed by Microsoft, leapfrogging many national efforts in generative AI and triggering fierce competition. Giants including Microsoft, Google, and Meta are investing billions annually in AI R&D, often outspending national public research programmes. China's Baidu, Alibaba, Tencent and AI companies such as DeepSeek are acting similarly, but in an entirely different political and societal context.

Healthcare: Philanthropic foundations fund high-risk, long-term biomedical and global health research where governments have retreated. The Gates Foundation funded mRNA vaccine platforms before COVID-19 and has spent more than $10 billion on vaccine R&D since its inception, while the Wellcome Trust is a major backer of genomics research globally.

Venture-backed fundamental research: Companies are attracting billions in private investment and hiring top academic talent to undertake basic research in areas requiring the kind of costly physical infrastructure that would once have been affordable only by governments, such as autonomous vehicles, orbital infrastructure, quantum computing and fusion power.

Box 2: The Rise of Tech Diplomacy

2.3 Time to rethink science diplomacy

The changing scientific and diplomatic environment calls for a fundamental rethink of science diplomacy.[46,47] Two major attempts at updating the framework were published in February 2025: the first by AAAS and the Royal Society; the second by the European Union.

The **AAAS** and the **Royal Society** published *Science Diplomacy in an Era of Disruption*[48] following a two-year global consultation. The original three-pillar typology set out on their 2010 report *New Frontiers in Science Diplomacy*—science in diplomacy, diplomacy for science, and science for diplomacy— had come under growing scrutiny. Critics noted that "science in diplomacy" underestimated the complexity of policy-making and geopolitical constraints in bilateral and multilateral diplomacy. It was suggested that "diplomacy for science" risked over-simplifying international collaboration by treating it as a uniform category; and that "science for diplomacy" sometimes overstated science's power to resolve deep-rooted conflicts.[49]

The new AAAS/Royal Society report responded to these critiques by introducing a reduced and restructured framework that proposed just two core dimensions: science impacting diplomacy; and conversely, diplomacy impacting science:

Science impacting diplomacy: How scientific knowledge and actors influence diplomatic objectives. This includes not only scientific advisers and national academies, but also multilateral advisory mechanisms like the IPCC or the G7 Science Academies. It captures science's role in shaping diplomatic agendas, supporting negotiation processes, and informing global policy in areas such as climate, health, and technology.

Diplomacy impacting science: How diplomatic tools and geopolitical considerations shape the scientific enterprise. This includes both enabling collaboration and imposing limits —through export controls, research security protocols, and trade negotiations— to promote or safeguard national or economic interests, reflecting the increasing use of politics and diplomacy to set boundaries on the circulation of knowledge.

This updated framework offers a more integrated and realistic account of how science and diplomacy interact in today's fragmented and strategic context, highlighting the complex realities of power, politics and expertise.

The **European Union** also consulted widely when developing its European Framework for Science Diplomacy, through a continent-wide co-creation process involving 130 experts from all member states.[50] In contrast to its 2016 motto "open to the world,"[51] the EU now articulates a more guarded position: "as open as possible, as closed as necessary."

On one hand, the EU seeks to preserve scientific openness, foster peaceful cooperation and promote multilateralism through platforms like the Horizon Europe funding programme. On the other hand, it explicitly aims to close the innovation gap with the US and China in frontier technologies, increase European competitiveness, and secure strategic autonomy in critical areas such as AI, clean energy, and biotech. In doing so, the EU acknowledges the complex dual mission of science diplomacy: to serve both the global public good and Europe's own strategic interests. This tension is further exacerbated by the blurring lines between civilian and military research, which have traditionally operated under separate funding and policy tracks.

Importantly, the EU report adds a fourth dimension to the 2010 AAAS/Royal Society framework by recognising the scientific community itself as a diplomatic actor. This new dimension, "**diplomacy in science**", highlights how scientific institutions increasingly employ diplomatic strategies to achieve their objectives: for example, engaging with UN bodies, advocating for global standards or suspending collaboration in response to geopolitical developments. In this view, science diplomacy is not just a tool for governments, but also an instrument of autonomous scientific actors navigating global politics.

Based on these revisions to the conceptualization of science diplomacy, GESDA proposes a set of principles to guide the evolution of science diplomacy for a renewed multilateralism:

1. Anticipate transformative breakthroughs by emphasising the opportunities they represent, not just the challenges and risks they may pose.

2. Focus on real-world early applications, not abstract principles by orienting discussions and action around real-world practices, providing actionable guidance for politicians, diplomats, policy-makers, and scientists, rather than discussions becoming an end in themselves.

3. Acknowledge the geopolitical context by leveraging competitive dynamics to find new avenues for cooperation, unlocking agile, responsive coalitions which can rapidly create and test blueprints for action. These prototypes, once proven, can be adopted and scaled up by the multilateral system, thus circumventing the gridlock that can arise from attempts to achieve global consensus directly.

4. Broaden stakeholder communities by acknowledging that both state and non-state entities may use science diplomacy: industry, philanthropic organisations, the media and citizens are now integral players, as well as the scientists themselves.

5. Build transdisciplinary capacity to navigate disruption by providing practitioners across sectors with the tools to understand, anticipate, and govern emerging science. Break down disciplinary silos to foster adaptive, systems-level leadership capable of managing complexity, embracing uncertainty, and converting disruption into shared progress.

In the remainder of this paper, we consider the first of these principles —the need for anticipation — in greater detail and then illustrate how all principles converge under GESDA's anticipatory approach to science diplomacy.

It is no longer sufficient, if it ever was, for diplomacy to address advances in science and technology as they become manifest: it must begin to consider and address their consequences as soon as these become foreseeable, at least in outline.

That requires going beyond the traditional reactive approach, in which technologies are allowed to play out and governance and regulation applied retrospectively if the need becomes apparent.

It is in developing the new and more proactive approach of science anticipation that GESDA has concentrated its efforts.

Figure 1: Science diplomacy for a renewed multilateralism

3. Use the future to build the present

3.1 The case for anticipation

Science and technology have become key drivers — if not *the* key driver — of international relations. Scientific and technological breakthroughs are transforming every dimension of society, from global economic systems, energy generation and industrial processes to our social worlds, interpersonal interactions and even the ways our bodies and minds work.

But many of these breakthroughs — such as social media, big data, or artificial intelligence — have been introduced to society without due consideration being paid to appropriate global governance frameworks. As a result, risks have gone unmanaged and opportunities untapped, with the incentives for those developing and promoting these technologies sometimes diverging from those of society at large.

The same pattern is now being repeated with the next wave of emerging technologies: human genome editing, synthetic biology, robotics, climate engineering, and others. If this continues, the resulting disruptions will produce profound, and sometimes unintended or undesirable consequences for our identities, relationships, and environments.

The Geneva Science Diplomacy Anticipator (GESDA) was established in 2019 by the Swiss and Geneva governments to address three fundamental questions:

— **What does it mean to be human** in the age of robots, gene editing and augmented reality?

— **How can technology reduce inequality** and foster inclusive development and well-being?

— **How can we supply the world with food and energy** while also safeguarding and regenerating our environments?

Humanity can harness the full transformative potential of science only if scientific advances, their impacts, and their governance are all addressed together. This requires anticipation —from the Greek meaning “to seize beforehand”: that is, combining a forward-looking mindset with the capacity for deliberate action in the present. The key to ensuring that science diplomacy remains fit for purpose, open and inclusive in this fast-moving era is therefore **science anticipation.**

GESDA’s main tool for science anticipation is the **GESDA Science Breakthrough Radar**®, a continually evolving exploration of around 40 science and technology domains where advances are expected to yield profound social, economic and environmental consequences. The Radar aims to capture both the nature of those potential advances and outline those consequences over the next 5, 10 and 25 years, based on a global collaboration of thousands of leading researchers, including those working in social sciences and humanities.[52]

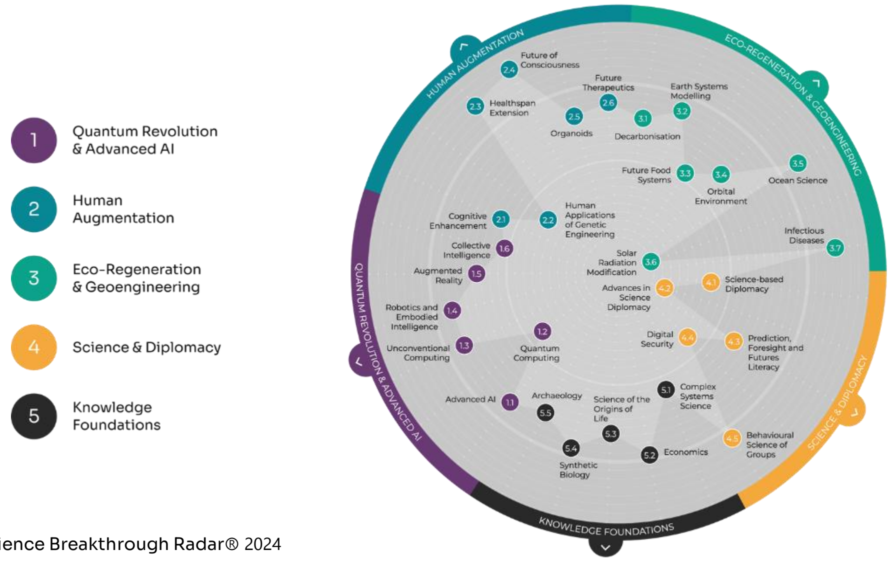


Figure 2: The GESDA Science Breakthrough Radar® 2024

The Radar provides the basis for GESDA to act as an honest knowledge broker between the scientific community, diplomats, citizens, philanthropists and the private sector. The insights it offers encourage open debates about what actions can be taken today to ensure that emerging scientific breakthroughs benefit as many people as possible tomorrow — before becoming disruptive or exacerbating existing geopolitical tensions and societal inequalities.

3.2 Realising opportunities, mitigating risks

Since the speed and scale of scientific development is likely to continue to accelerate —perhaps dramatically, through the application of AI and quantum computing in scientific research— one way science diplomacy can evolve is by embedding the scientific method into diplomatic action, grounded in international collaboration, open peer review, and continuous self-correction and adaptation.

The need to anticipate emerging science is rapidly gaining traction as a core principle of global governance and action to manage technologies with high societal impact and dual-use potential.[53] In 2024, the United Nations Summit of the Future aimed to strengthen multilateralism and enhance global cooperation in science and technology to address pressing challenges and align nations on the ethical advancement of disruptive technologies such as AI, emphasizing the voices of youth and future generations.

A growing number of international bodies have articulated policy frameworks for anticipatory governance of emerging technologies, aimed at equipping societies and institutions with the tools and capacities to navigate the opportunities of rapid scientific advancement.

Notably, the OECD's 2024 Framework for Anticipatory Governance of Emerging Technologies provides structured guidance on how governments can embed anticipation into policy cycles, stakeholder engagement, and innovation strategies.[54]

Governments, think tanks and UN bodies such as the UN Secretary General Scientific Advisory Board (SAB), UNESCO, WHO and the UN Human Rights Council have issued forward-looking briefings, policy recommendations, resolutions and governance proposals for fields including AI, quantum computing, neurotechnology, synthetic biology or climate geoengineering —all areas where both scientific uncertainty and disruption potential are high.[55]

But while there is widespread agreement on the importance of cultivating anticipatory mindsets and capabilities, most of these anticipatory frameworks emphasize a risk-based approach, focusing on the potential threats posed by emerging science rather than fully realising the opportunities they create.

> Science offers immense value for shaping diplomatic frameworks that can evolve with the pace of innovation. Anticipation in science diplomacy can help to better integrate, adapt, and harness scientific breakthroughs and align them with global norms, shared values and societal needs.

3.3 The GESDA Framework on Anticipatory Science Diplomacy

The **GESDA Anticipatory Science Diplomacy framework** strengthens the multilateral system by enabling the diplomatic, scientific, business and citizen communities to proactively govern and deploy scientific advances together. This framework rests on four pillars.

Science anticipation. Identify and scope out the major scientific advances with the highest potential to reshape humanity and the planet, as GESDA does for five-, ten- and 25-year timescales.[1]

Honest brokering. Convene and connect diverse communities to discuss and align early on the implications and applications of emerging science, thus expanding the scope for action in the present.[2,3]

Global action. Prototype early multilateral solutions and frameworks that maximise the benefits of future science advances and minimise their potential risks.

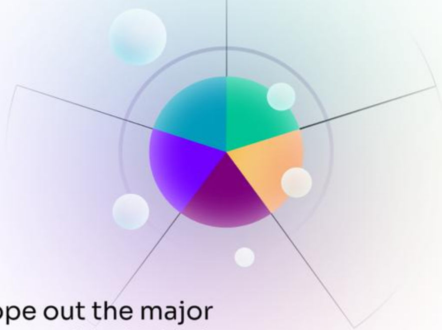
Capacity building. Empower communities and leaders with the tools to anticipate, understand, harness and govern emerging science for the benefit of humanity.

GESDA's anticipatory framework represents a vital evolution in the field: one that integrates strategic anticipation with multilateral values, balances openness with security and promotes inclusive and actionable governance to harness the positive applications of emerging science and technology.

Combining experimentation and pragmatism, this approach provides actors with early insights into frontier science, allowing sufficient time to assess and debate their long-term global implications, and avoid missed opportunities by proactively shaping innovation trajectories before crises emerge.

In doing so, GESDA contributes not only to bridging the gap between science and diplomacy, but also to operationalizing anticipation as a core diplomatic competency.

The GESDA Framework on Anticipatory Science Diplomacy



Science anticipation

Identify and scope out the major scientific advances with the highest potential to reshape humanity and the planet, as GESDA does for five-, ten- and 25-year timescales.

Honest brokering

Convene and connect diverse communities to discuss and align early on the implications and applications of emerging science, thus expanding the scope for action in the present.

Global action

Prototype early multilateral solutions and frameworks that maximise the benefits of future science advances and minimise their potential risks.

Capacity building

Empower communities and leaders with the tools to anticipate, understand, harness and govern emerging science for the benefit of humanity.

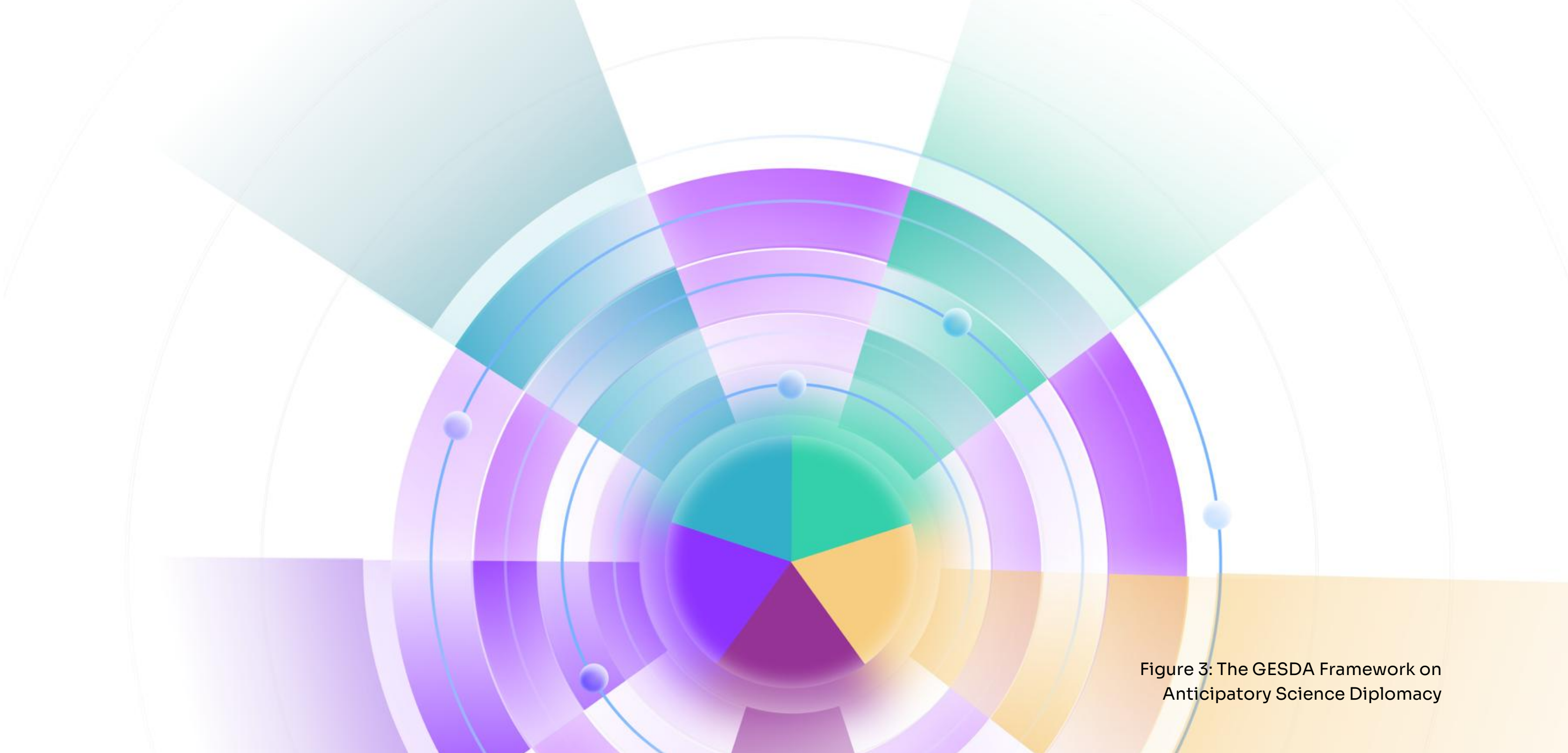


Figure 3: The GESDA Framework on Anticipatory Science Diplomacy

GESDA and the UN Security Council

GESDA's anticipatory science diplomacy has served Switzerland in its mandate as an elected member of the UN Security Council. Switzerland mobilised GESDA's expertise to put the consequences of technological developments for peace and security on the Council's agenda.[56]

A presidential statement negotiated under Swiss leadership recognised for the first time the role of science in fulfilling the Security Council's mandate and extended its willingness to incorporate scientific advances more systematically into its work.

These activities have enabled Switzerland to demonstrate the contribution that science can make to diplomatic efforts, particularly in the context of good offices, peace promotion and global governance, while strengthening the link with International Geneva.

Box 3: GESDA and the UN Security Council

3.4 Case study: building the Open Quantum Institute

As an international independent think- and do-tank, honest broker platform and capacity builder, GESDA can incubate innovative science diplomacy initiatives faster than the traditional diplomatic processes allow, and following a rapid design and prototyping phase, inject them into the multilateral system.

One example is GESDA's incubation of the **Open Quantum Institute (OQI**), now hosted at CERN in Geneva and supported by UBS,[57] as the first anticipatory science diplomacy instrument for a technology that has not yet reached widespread practical application: quantum computing.

The development of OQI illustrates the effectiveness of GESDA's framework for anticipatory science diplomacy, using a proactive, multi-stakeholder methodology, and how it differs from the instruments and processes of traditional science diplomacy.

Anticipating future science breakthroughs.
The 2021 edition of the GESDA Science Breakthrough Radar anticipated that quantum computing has the potential to disrupt critical sectors of the global economy from battery design to drug discovery, finance and national security. Research and development are ongoing to confirm the specific applications for which quantum computers will outperform conventional computers.

The timeframe is also significant. Experts converged on initial societal impact taking place within five to ten years, with applications in cryptography being the first to reach maturity. That puts quantum computing within the critical "anticipatory window" — the period of time between scientific advances becoming conceivable and their actual deployment in the real world. It is during this window that there is the greatest opportunity to intervene.

Understanding and bridging mindsets across four communities.
Acting as an honest broker, GESDA convened a task force of researchers from academia and the private sector, diplomacy (including both Geneva-based ambassadors and UN representatives), industry and civil society to scope out options for accelerating the societal benefits of quantum computing.

GESDA brought these communities together in "Anticipatory Situation Rooms". These are structured workshops which develop and pilot new initiatives to identify gaps in understanding, help stakeholders grasp each other's world-views, motivations, incentives, constraints and timescales, and thereby shape future solutions.

Engaging in discussions early — before the technology reaches maturity for military use or large commercial deployment — allowed for strategic, governance and ethical considerations to be addressed openly. This "learning by doing" approach builds trust and empowers stakeholders.

Shifting from early warning to early action. Anticipation is of consequence only if it leads to action. The task force concluded that anticipatory science diplomacy action was needed in order to:

— mobilise quantum experts to explore quantum computing applications which could support the UN's 2030 Agenda, particularly given that such exploration had so far been conducted almost exclusively by defence and finance conglomerates;

— address the risk of creating a new digital divide, with the majority of regions unable to invest in quantum computing themselves or access suitable resources elsewhere, and thus lacking understanding of its potential;

— navigate the growing geopolitical fragmentation around quantum computing, widely considered a critical technology for national sovereignty.

By end of 2022, all task force members and their organisations had agreed to commit time and resources to test a novel science diplomacy instrument: the Open Quantum Institute.

Seizing opportunities and benefits, mitigating risks and threats. Much of the diplomatic discussion of quantum computing has been around its risks — for example, its potential use in circumventing encryption. The OQI, on the other hand, singled out 18 concrete problems encountered by UN organisations and NGOs for which quantum computing might provide a solution.

The OQI constituted interdisciplinary teams to explore use cases such as the acceleration of new antibiotics discovery with the Global Antibiotic Research & Development Partnership (GARDP)[58] or improving water management with efficient water leak detection with UN Habitat.[59]

This practical, solution-focused approach is the basis for the first OQI pillar — *Accelerating Applications for Humanity.* [60] The second pillar — *Access for All* — aims at bringing quantum resources to underserved geographies. The OQI partners with industry providers to grant safe, global and inclusive access to a pool of public and private quantum computers and simulators available via the cloud for the exploration of use cases surfaced by local communities or for select educational purposes.

Source: Marc Bader, GESDA Summit Geneva 2024

Strengthening engagement with science and building capacity.
The third pillar of the OQI's work is *Advancing Capacity Building*, under which the institute develops educational tools that are a low-threshold way of learning about quantum computing and its applications. The OQI enables quantum-underserved geographies to learn about quantum computing and contribute to the development of its applications.

For instance, the OQI has developed the concept of "hackathons in a box",[61] now being implemented across the globe from Costa Rica to Ghana. This, in turn, provides the foundation for early adoption of the technology and to contribute to scientific advances, in particular with respect to quantum algorithm development. It also helps policy-makers and diplomats to improve their understanding of quantum technologies.

The OQI's fourth pillar, *Activating Multilateral Governance for the SDGs*,[62] translates the latest scientific and technological advancements into actionable insights for policy audiences. This is particularly valuable to seize opportunities for specific countries but also for safeguarding against the potential cryptographic threats posed by quantum computers. Anticipating and experimenting with upcoming breakthroughs at such early stage becomes both an avenue for solving problems and promoting new paths towards shared prosperity — as well as the best deterrent against threats and misuses of science and technology. The OQI's membership includes countries that are not currently considered as "quantum powers", therefore serving as a global neutral forum for early and meaningful diplomatic engagement.

Embracing "Plurilateralism".
GESDA's anticipatory practices reflect a broader vision of multilateralism, better termed plurilateralism, rooted in our globalised world despite the current episode of fragmentation. Coalitions of state and non-state actors — including governments, corporations, universities, philanthropic networks and citizen groups — collaborate to pursue shared goals. While nation-states and traditional diplomacy remain essential, non-state actors often operate with greater agility, speed and scale.

The OQI is fundamentally plurilateralist by design, bringing together the political-diplomatic community through its work on quantum governance and advancing use cases for the SDGs. The OQI has created a platform for collaboration between academic researchers, researchers from industry and SDG "problem owners" to rigorously develop scientifically sound quantum use cases addressing the SDGs. By having the SDGs at its centre and working closely with SDG problem owners, citizens and the environment are brought into the development of use cases as strong and central stakeholders.

To this end, the OQI is the only forum where actors and stakeholders from different communities and countries come together and undertake clear, actionable, common-goal joint activities. This is particularly noteworthy in times of heightened geopolitical tensions and the industrial competition affecting the quantum-computing community at large, which has effectively reduced the scope for international cooperation.

The agile and action-driven structure of the OQI, with its four pillars supported by a multi-stakeholder community, enables it to realise its ambitious mission despite the increasingly challenging global context. It is a real, working example of anticipatory science diplomacy in action.

Importantly, the OQI's approach contributes to the societal acceptance of novel technologies, based on transparent communication of scientific processes and uncertainties, and clarifying where knowledge is evolving and where gaps persist. Trust in science is boosted when stakeholders have confidence that any potential risks and threats are being responsibly and proactively anticipated and tackled. By openly addressing concerns like safety, privacy or security early on, the OQI builds public trust.

Accelerating quantum computing applications for the benefit of humanity

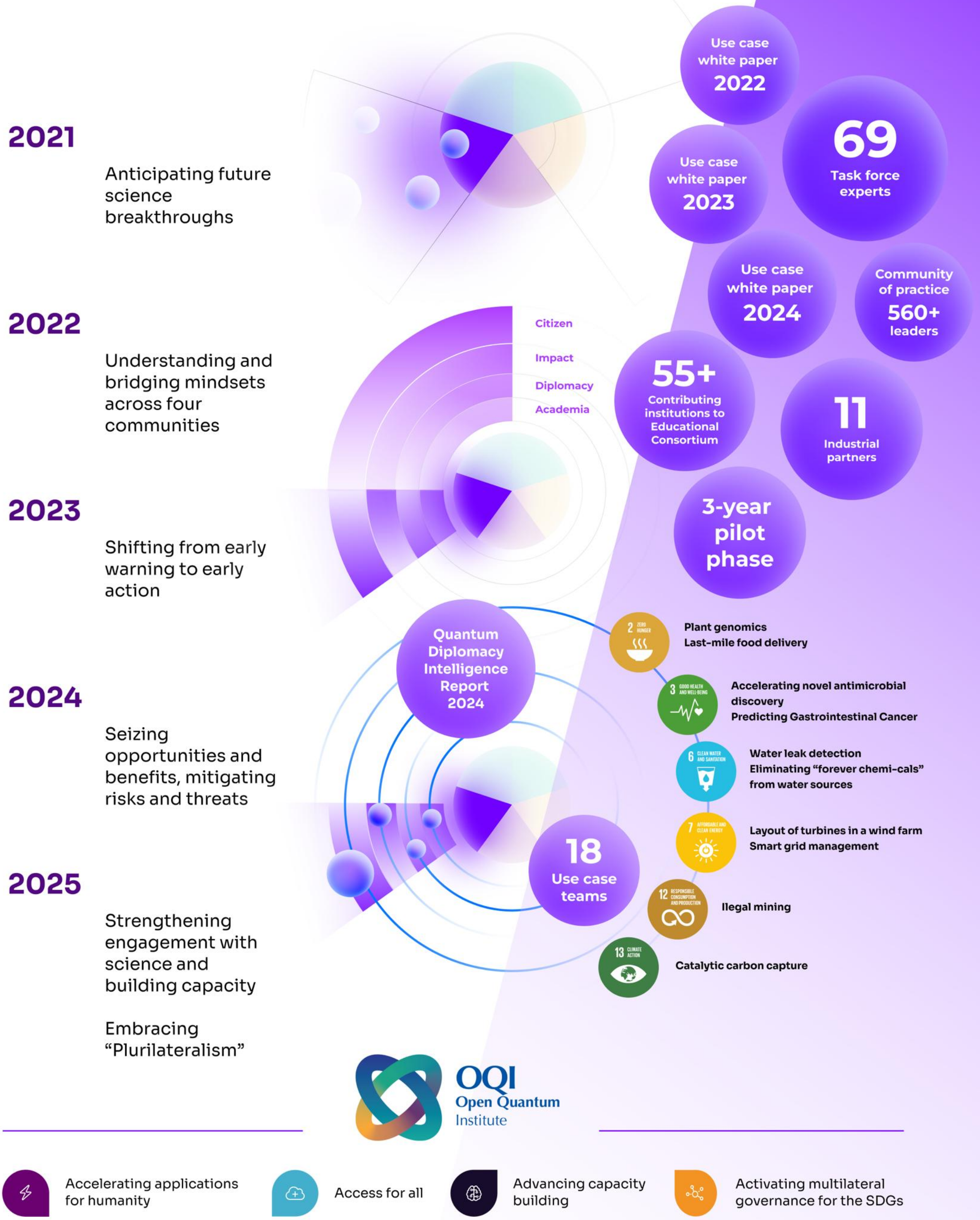


Figure 4: Accelerating quantum computing applications for the benefit of humanity

4. Anticipatory Leadership

4.1 Preparing leaders for a world accelerated by science and technology

Navigating the complex interplay between science and technology advancements, geopolitical dynamics, and the changing global order requires updating the way how leaders in science, diplomacy, business as well as citizens at large are trained. [63]

Landscape analyses of science diplomacy training around the world, by both GESDA and others,[64] have found that existing offerings are fragmented, uncoordinated and not yet embedded in mainstream educational programmes. Future leaders will need to anticipate emerging trends, understand their scientific, policy, business, economic and societal dimensions, and develop the 'capacity to act' early enough to steer them towards tackling some of humanity's biggest challenges.

To address this, GESDA launched an interdisciplinary curriculum framework in

2023 to prepare leaders and decision-makers in all fields for a world accelerated by science and technology.[65]

Anticipatory leadership encompasses a set of key competencies for addressing emerging opportunities and challenges; navigating the complexities and polarities of a rapidly changing global landscape; and helping the world to benefit faster and more effectively from advances in science and technology.

Anticipatory leadership infuses principles from the world of science into politics and diplomacy, private sector and society at large that are essential to navigate our changing world: scientific literacy, international collaboration, continuous self-correction and adaptation, consensus building, openness, adaptability, and thriving in uncertainty.

GESDA's **Anticipatory Leadership Training Framework** accordingly provides a four-pillar curriculum backbone outlining the core competencies — knowledge, skills, attitudes and mindsets— needed to prepare leaders for this changing world.

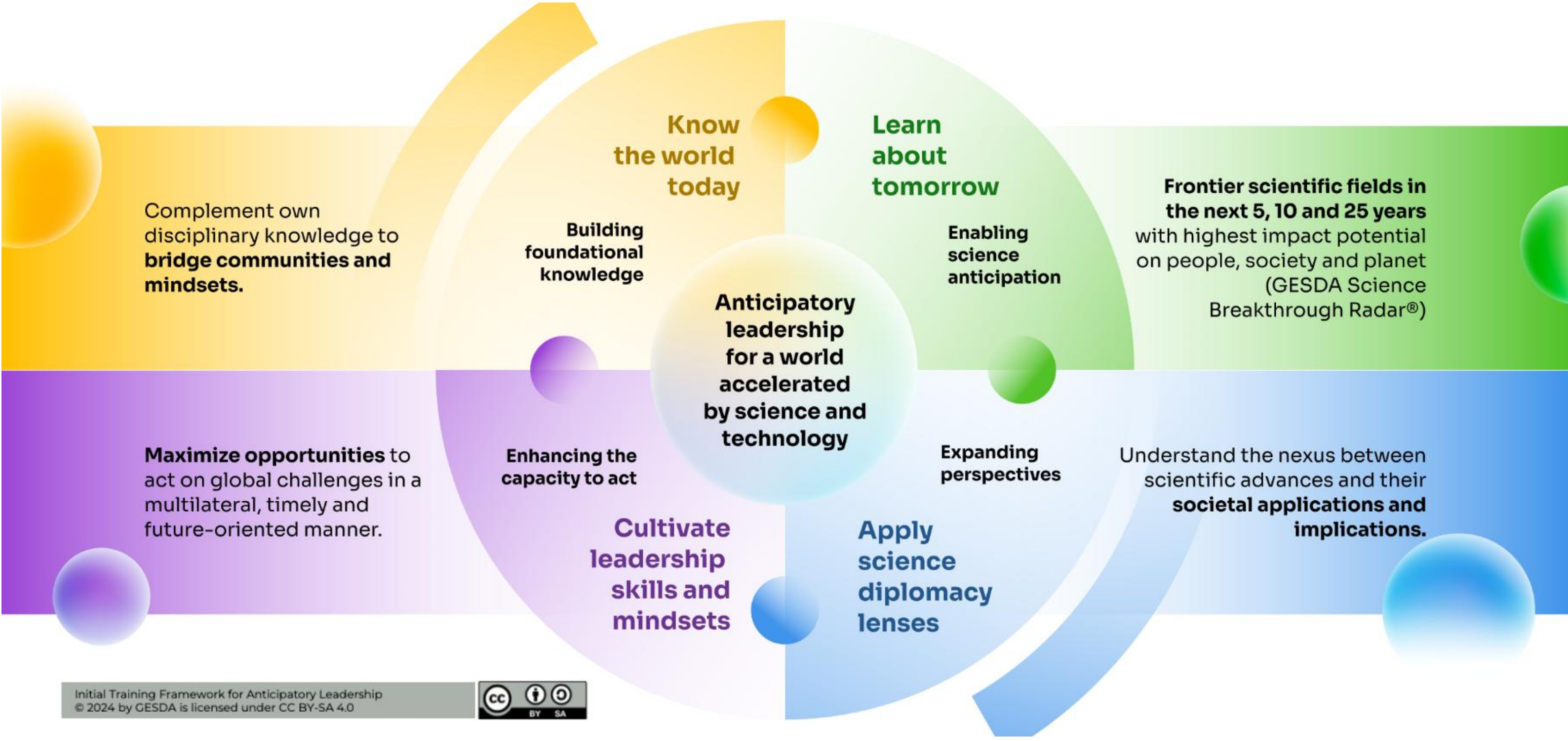


Figure 5: GESDA's Anticipatory Leadership Training Framework

GESDA's Anticipatory Leadership Training Framework

Know the world today: Complement own disciplinary knowledge to understand other fields and bridge mindsets between academia, diplomacy, business and citizens.

Learn about tomorrow: Anticipate future scientific developments at 5-10-25 years with the highest transformative potential for people, society and the planet, as captured in the GESDA Science Breakthrough Radar.

These include AI, quantum, human augmentation, synthetic biology, ecosystems regeneration or geoengineering, as well as the future of social systems, geopolitics, democracy or the economy and the future of research itself, among many others.

Apply science diplomacy lenses: Apply the lenses of science and diplomacy to understand the links between scientific advances and their societal applications and impacts — including on peace and security, development, multilateral governance, ethics, geopolitics and human rights.

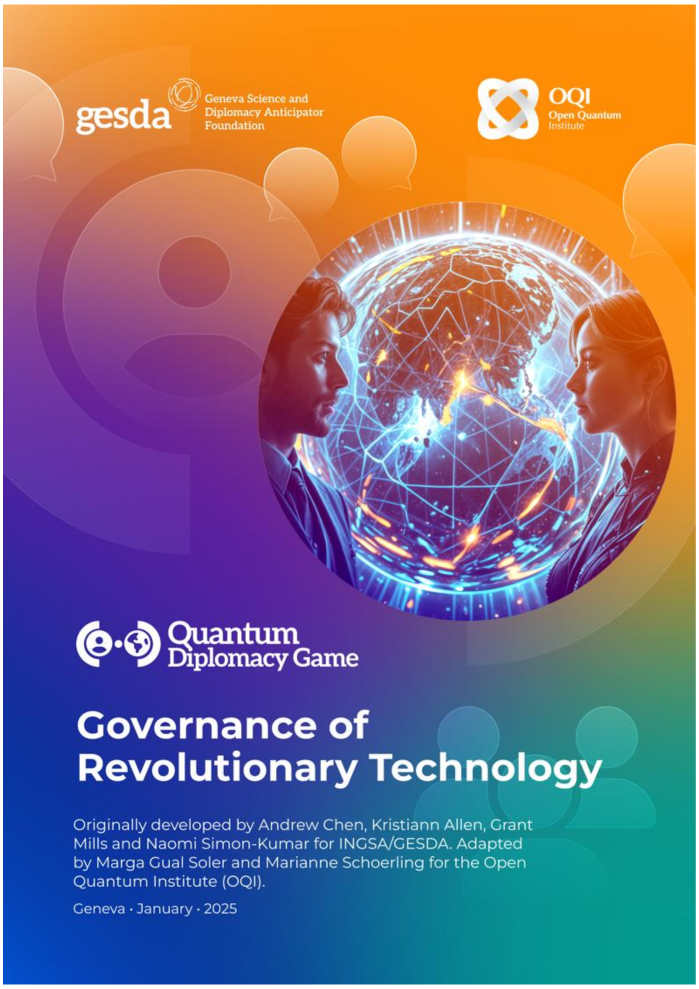
Cultivate leadership skills and mindsets: Build the capacity to act through experiential learning and better appreciation of how others react and behave, think and act to maximize opportunities to address global challenges that don't just replicate models of the past but promote a future-oriented multilateralism.

Box 4: GESDA's Anticipatory Leadership Training Framework

4.2. GESDA's experiential learning methodology

GESDA's approach to anticipatory science diplomacy training is based on experiential learning — immersion in fictional scenarios that explore complex realities in a controlled environment. Simulations, games and speculative futures exercises allow participants from different backgrounds to collectively explore and experiment, practice negotiation and collaboration, and anticipate outcomes of scientific and diplomatic decisions in a safe, simulated yet stimulating environment.[66]

These methodologies help navigate the rapidly shifting frontiers of science and technology, highlighting how scientific breakthroughs can drive transformative changes in society, geopolitics, and economics — and empower leaders in academia, policy, business and society to act in the present to shape positive futures, ensuring that tomorrow's technologies will benefit all, before they become sources of tensions or exacerbate global inequalities.[67]



Source: Quantum Diplomacy Game, GESDA 2025

The GESDA anticipatory science diplomacy experiential methodology follows three steps, as illustrated by the Quantum Diplomacy Game:[68]

1. Seeing the future. First, participants explore a fictional future scenario where an emerging technology rooted in the GESDA Science Breakthrough Radar has been fully realised. This exposes the potential challenges that might arise if the technology advances without adequate governance, meaning both risks that go unaddressed and opportunities that might be squandered.

2. Using the future to build the present. The simulation 'rewinds' back to the present day. Participants are assigned roles in the science diplomacy ecosystem — scientists, diplomats, industry, citizens, media— and discuss what actions, if taken today, could prevent or mitigate the negative outcomes seen in the future scenario, proposing policies, principles, or partnerships to ensure scientific development for the common good before the real-world trajectory reaches the anticipated crisis point.

3. Evaluating science diplomacy in practice. The simulation concludes with a debrief, analysing the outcomes and decisions within the game and considering whether those choices led towards a more positive or negative outcome compared to the original scenario.

Drawing connections between the game experience and real-world science diplomacy challenges surfaces lessons that apply to actual policy-making or international diplomacy. In doing so, the game serves as a mirror, helping leaders practice anticipatory decision-making and then critically examine it in a safe environment before facing similar issues in the real world.

What sets anticipatory leadership apart is its ability to thrive in uncertainty and complexity. Unlike traditional leadership models that seek stability and control, anticipatory leadership embraces constant evolution—it is inherently revisable, iterative, and designed to update as new knowledge emerges.

It draws inspiration from the scientific method itself: treating cooperation and competition not as opposites to be resolved, but as dynamic polarities to be balanced.

This anticipatory mindset, skillset and toolset equips leaders to navigate disruption with curiosity, humility, and adaptability - qualities essential for shaping inclusive, future-ready governance in our rapidly changing world.

Source: Marc Bader, Geneva Science Diplomacy Week 2025

5. Conclusion

In an era marked by accelerating scientific breakthroughs and geopolitical fragmentation, anticipatory science diplomacy offers a necessary evolution of the field. It represents a proactive, forward-looking approach that integrates strategic anticipation with multilateral values, aiming to harness scientific advancements for the benefit of all. Unlike traditional, reactive science diplomacy, this approach enables stakeholders to engage early in shaping the trajectory of emerging technologies, such as AI, quantum computing, neurotechnology, synthetic biology or climate interventions, before they become disruptive or exacerbate inequalities.

GESDA's unique contribution lies in its anticipatory science diplomacy framework, built on science anticipation, honest brokering, global action and capacity building. By embedding anticipation into the diplomatic process, GESDA expands the window for evidence-informed governance and deployment of future science. It recognises knowledge as a resource that must be stewarded responsibly and ensures that discussions are grounded in real-world applications, not abstract definitions. Anticipatory science diplomacy allows for action-oriented, inclusive, and adaptive governance that balances openness with legitimate societal, security, and geopolitical concerns.

Acting within the critical anticipatory window between potential scientific breakthroughs and their actual deployments enables stakeholders to jointly decide how to take these developments forward. By considering the future as a range of possibilities, actors can make better informed decisions in the present to influence what happens in the future, allowing diplomacy to keep pace with research and innovation, and proactively shaping innovation trajectories to allow opportunities to be explored while putting in place appropriate guardrails against excessive or poorly understood risks.

In developing and implementing GESDA's approach to science anticipation, and its integration in diplomacy and leadership, we have found five lessons which we believe have broad relevance for the future of science diplomacy:

1. Anticipate transformative breakthroughs proactively, not reactively: Identify emerging scientific and technological developments with the potential to reshape humanity and the planet before they are deployed into the world. Tackling the opportunities and risks of emerging science early on enables governance to shift from reactive to proactive.

2. Focus on real-world application, not abstract principles: Shift science diplomacy from concept-heavy, risk-dominated discourse to opportunity-driven, practice-based engagement. Ground discussions in tangible, actionable use cases that guide diplomats, policymakers, scientists and private sector leaders.

> In a fragmented geopolitical landscape, global consensus may not always be possible —but coalitions of the willing can act rapidly to provide blueprints for the multilateral system to adopt and scale.

3. Embrace geopolitical complexity to accelerate collaboration: Recognise that international scientific collaboration exists within an environment of power competition. By acknowledging this, science diplomacy can leverage competitive dynamics to open new avenues for cooperation —circumventing the gridlock of consensus-based multilateralism and unlocking agile, responsive coalitions.

4. Expand the community of actors: Science diplomacy is no longer the sole domain of states and must include the private sector, philanthropic foundations, civil society, and media as essential participants in shaping future governance and innovation agendas.

5. Build interdisciplinary capacity to navigate disruption: Equip leaders across sectors with the tools to understand, deploy and govern emerging science. Break down disciplinary silos to foster adaptive, systems-level leadership capable of managing complexity, embracing uncertainty, and converting disruption into shared progress.

By applying these principles, GESDA has demonstrated that anticipation can lead to practical solutions. The Open Quantum Institute and the Anticipatory Leadership curriculum illustrate how this model bridges science, diplomacy, the private sector, and society to produce timely and inclusive governance strategies.

Looking ahead, anticipatory science diplomacy will be essential to ensuring that international cooperation keeps pace with disruptive innovations.

In an era of deepening fragmentation and rising barriers to cooperation, science remains one of the few universal bridges with the power to connect all people and nations. Science can open spaces for dialogue among actors who might no longer meet at the same table, preserving the open and safe circulation of people, data, and ideas.

Anticipatory science diplomacy and anticipatory leadership can unlock new modes of engagement where traditional diplomacies stall.

GESDA's model provides a working demonstration of how science can remain a bridge rather than a battleground amid geopolitical tensions. Anticipatory leadership —rooted in the scientific method's values of openness, adaptability, and iterative learning—offers the diplomatic and societal frameworks needed to thrive amid uncertainty.

As GESDA continues to shape this evolving field from International Geneva, it also contributes to reinforcing Switzerland's role as a hub for innovation and diplomacy. Its approach offers both inspiration and practical guidance for multilateral organisations, national governments, and non-state actors alike.

In a world where the pace of scientific advancement often outstrips our ability to respond, GESDA's new kind of science diplomacy – one that doesn't wait for crises to react but proactively aligns stakeholders around the future we want - provides a roadmap to ensure that the benefits of science can reach everyone.

6. References

1 Geneva Science and Diplomacy Anticipator, 'GESDA's approach to Science Anticipation', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global/science-anticipation/introductory-essay-gesd-as-approach-to-science-anticipation

2 Geneva Science and Diplomacy Anticipator, 'Acting as an honest broker', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global/science-anticipation/acting-as-an-honest-broker

3 Geneva Science and Diplomacy Anticipator, 'Methodology', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global/science-anticipation/methodology

4 J. A. Millward, 'The technological silk road', in 'The silk road: a very short introduction', Oxford University Press (2013), https://doi.org/10.1093/actrade/9780199782864.003.0004

5 J. Simone, '150 years ago, the Metre Convention determined how we measure the world — a radical initiative for the time', The Conversation (2025), https://theconversation.com/150-years-ago-the-metre-convention-determined-how-we-measure-the-world-a-radical-initiative-for-the-time-252108

6 World Health Organization. Regional Office for South-East Asia, 'History of international co-operation for health', in 'Twenty years in South-East Asia 1948-1967', WHO Regional Office for South-East Asia (1967), https://iris.who.int/bitstream/handle/10665/126401/Chapter%20-1.pdf?sequence=9&isAllowed=y

7 International Atomic Energy Agency, 'The Geneva Conference — how it began', International Atomic Energy Agency Bulletin, 6 (1964), https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull6-3/06305100303.pdf

8 K. E. Höne and J. Kurbalija, 'Accelerating basic science in an intergovernmental framework: learning from CERN's science diplomacy', Global Policy, 9 (2018), https://doi.org/10.1111/1758-5899.12589

9 P. A. Berkman et al., 'Science diplomacy: Antarctica, science and the governance of international spaces', Smithsonian Institution Scholarly Press (2011), https://repository.si.edu/bitstream/handle/10088/16154/SD.Berkman.web.FINAL.pdf

10 V. C. Turekian and N. P. Neureiter, 'Science and diplomacy: the past as prologue', Science & Diplomacy (2012), https://www.sciencediplomacy.org/editorial/2012/science-and-diplomacy-past-prologue

11 'History', Pugwash Conferences on Science and World Affairs, https://pugwash.org/history

12 Office of Science & Technology Cooperation and Bureau of Oceans & International Environmental & Scientific Affairs, 'Biennial Report to the U.S. – China Economic & Security Review Commission', Department of State, United States of America (2006), https://2001-2009.state.gov/documents/organization/96437.pdf

13 S. J. Pastrana et al., 'Promoting scientific cooperation in times of diplomatic challenges: sustained partnership between the Cuban Academy of Sciences and the American Association for the Advancement of Science', MEDICC Review, 20 (2018), https://mediccreview.org/promoting-scientific-cooperation-in-times-of-diplomatic-challenges-sustained-partnership-between-the-cuban-academy-of-sciences-and-the-american-association-for-the-advancement-of-science

14 B. M. Dolan, 'Science and technology agreements as tools for science diplomacy: a U.S. case study', Science & Diplomacy (2012), https://www.sciencediplomacy.org/article/2012/science-and-technology-agreements-tools-for-science-diplomacy

15 'The Antarctic Treaty', Secretariat of the Antarctic Treaty, https://www.ats.aq/e/antarctictreaty.html

16 'The Montreal protocol on substances that deplete the ozone layer', Ozone Secretariat (1987), https://ozone.unep.org/treaties/montreal-protocol

17 'The Paris Agreement', UN Climate Change, https://unfccc.int/process-and-meetings/the-paris-agreement

18 'Smallpox Eradication Programme — SEP (1966-1980)', World Health Organization (2010), https://www.who.int/news-room/feature-stories/detail/the-smallpox-eradication-programme---sep-(1966-1980)

19 'United Nations Convention on the Law of the Sea', International Maritime Organization, https://www.imo.org/en/ourwork/legal/pages/unitednationsconventiononthelawofthesea.aspx

20 'History: looking back helps us look forward', Organisation for the Prohibition of Chemical Weapons https://www.opcw.org/about-us/history

21 'Key sectors', République et canton de Genève, https://www.ge.ch/en/teaser/entreprendre-geneve/key-sectors.

22 'Facts and figures about International Geneva', Mission of Switzerland to the UN in Geneva (2025), https://www.eda.admin.ch/missions/mission-onu-geneve/en/home/geneve-international/faits-et-chiffres.html

23 'The facets of multilateralism in Geneva', United Nations History Museum Geneva, https://museum.ungeneva.org/the-facets-of-multilateralism

24 'The right to access to and participate in science: special rapporteur in the field of cultural rights', UN Human Rights Office, https://www.ohchr.org/en/special-procedures/sr-cultural-rights/right-access-and-participate-science

25 'Federal Council appoints special representative for science diplomacy', Federal Department of Foreign Affairs FDFA [Switzerland] (2021), https://www.eda.admin.ch/eda/en/fdfa/fdfa/aktuell/newsuebersicht/2021/02/science-diplomacy.html

26 The American Association for the Advancement of Science (AAAS) and the Royal Society, 'New frontiers in science diplomacy' (2010), https://royalsociety.org/news-resources/publications/2010/new-frontiers-science-diplomacy

27 V. C. Turekian and T. Kishi, 'Science and technology advising in today's foreign policy', Science & Diplomacy (2017), https://www.sciencediplomacy.org/perspective/2017/science-and-technology-advising-in-todays-foreign-policy

28 'FMSTAN', International Network for Governmental Science Advice (INGSA), https://ingsa.org/divisions/fmstan

29 L. Melchor, 'What is a science diplomat?', The Hague Journal of Diplomacy, 15 (2020), https://doi.org/10.1163/1871191X-BJA10026

30 'Science Diplomacy Capital for Africa', https://www.africasciencediplomacy.org; Science Diplomacy Center: a regional initiative to foster science-policy dialogue and collaboration for a peaceful, prosperous and sustainable Americas', Inter-American Institute for Global Change Research, https://www.iai.int/en/post/detail/SDC

31 M. Gual Soler, 'Science diplomacy in Latin America and the Caribbean: current landscape, challenges, and future perspectives', Frontiers in Research Metrics and Analysis, 6 (2021), https://doi.org/10.3389/frma.2021.670001

32 See for example 'Research-industry grants for international collaboration', Global Science and Technology Diplomacy Fund [Australia], https://www.glodip.org.au; 'Science Diplomacy Fund (SDF)', NWO [Dutch Research Council], https://www.nwo.nl/en/researchprogrammes/international-programmes/science-diplomacy-fund-sdf

33 'Geneva Science Diplomacy Week 2025', Geneva Science and Diplomacy Anticipator (2024), https://www.gesda.global/geneva-science-diplomacy-week-2025

34 Directorate-General for Research and Innovation, 'Open innovation, open science, open to the world: a vision for Europe', European Commission (2016), https://publications.europa.eu/resource/cellar/3213b335-1cbc-11e6-ba9a-01aa75ed71a1.0001.02/DOC_2

35 'Secretary-General's Scientific Advisory Board', United Nations, https://www.un.org/scientific-advisory-board/en

36 'Science and diplomacy joint programme', United Nations Development Programme, https://mptf.undp.org/fund/jxj00

37 'UNESCO hosts global gathering to advance science diplomacy for peace', UNESCO (2025), https://www.unesco.org/en/articles/unesco-hosts-global-gathering-advance-science-diplomacy-peace

38 M. Gual Soler, 'A personal reflection on science diplomacy & COVID-19', International Network for Governmental Science Advice (INGSA), (2020), https://covid.ingsa.org/covidtag/covid-19-featured/gual-soler-april.

39 T. Flink, 'The sensationalist discourse of science diplomacy: a critical reflection', The Hague Journal of Diplomacy (2020), https://doi.org/10.1163/1871191X-BJA10032

40 Geneva Science and Diplomacy Anticipator, 'Science-based diplomacy', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global/topics/science-based-diplomacy

41 Geneva Science and Diplomacy Anticipator, 'Technology diplomacy and the role of non-state actors', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global/sub-topics/technology-diplomacy-and-the-role-of-non-state-actors

42 'The TechPlomacy approach', Office of Denmark's Tech Ambassador, https://techamb.um.dk/the-techplomacy-approach

43 'Our work with the UN and international organizations', Microsoft, https://www.microsoft.com/en-us/corporate-responsibility/united-nations; 'Google at the 79th United Nations General Assembly', The Keyword, https://blog.google/outreach-initiatives/public-policy/google-united-nations-general-assembly-2024

44 J. Kurbalija, 'Will science diplomacy survive?', Diplo (2022), https://www.diplomacy.edu/blog/will-science-diplomacy-survive

45 Geneva Science and Diplomacy Anticipator, 'Science diplomacy for effective multilateralism', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global/sub-topics/science-diplomacy-for-effective-multilateralism

46 S. Balme, 'Evolving paradigms in science and tech diplomacy', Global Challenges, 17 (2025), https://globalchallenges.ch/issue/17/evolving-paradigms-in-science-and-tech-diplomacy

47 V. Turekian and P. Gluckman, 'Science diplomacy and the rise of technopoles', Issues in Science and Technology, 41 (2024), https://issues.org/science-diplomacy-technopoles-turekian-gluckman

48 Center for Science Diplomacy, 'Science diplomacy in an era of disruption: a 2025 report by the Royal Society and AAAS', American Association for the Advancement of Science (2025), https://www.aaas.org/news/science-diplomacy-era-disruption.

49 C. Rungius and T. Flink, 'Romancing science for global solutions: on narratives and interpretative schemas of science diplomacy', Humanities and Social Sciences Communications, 7 (2020), https://doi.org/10.1057/s41599-020-00585-w

50 European Commission: Directorate-General for Research and Innovation, 'European framework for science diplomacy: recommendations of the EU science diplomacy working groups', Publications Office of the European Union (2025), https://data.europa.eu/doi/10.2777/9235330

51 C. Moedas, 'Science diplomacy in the European Union', Science & Diplomacy, 5, (2016) https://www.sciencediplomacy.org/sites/default/files/science_diplomacy_in_the_european_union_science__diplomacy.pdf

52 Geneva Science and Diplomacy Anticipator, 'Home', GESDA Science Breakthrough Radar (2024), https://radar.gesda.global

53 'State-of-play and future trends on the development of oversight frameworks for emerging technologies', Rand Europe, https://www.rand.org/randeurope/research/projects/2024/governance-frameworks.html

54 OECD, 'Framework for anticipatory governance of emerging technologies', OECD Publishing (2024), https://doi.org/10.1787/0248ead5-en

55 See for example UNESCO, 'Highlights of the International Year of Quantum Science and

Technology 2025', UNESCO (2025) https://www.unesco.org/en/articles/highlights-international-year-quantum-science-and-technology-2025; Human Rights Council Advisory Committee, 'Impact, opportunities and challenges of neurotechnology with regard to the promotion and protection of all human rights', United Nations (2024), https://digitallibrary.un.org/record/4060417?v=pdf; 'Landscape analysis of the opportunities and challenges for neurotechnology in global health', World Health Organization (2025),https://www.who.int/publications/i/item/9789240109049

56 'Arria-Formula Meeting: Unlocking the Power of Science for Peace and Security', Switzerland's seat in the Security Council 2023-2024, https://www.aplusforpeace.ch/arria-formula-meeting-unlocking-power-science-peace-and-security

57 'The Open Quantum Institute', Open Quantum Institute, https://open-quantum-institute.cern

58 Accelerating novel antimicrobial discovery', Open Quantum Institute, https://open-quantum-institute.cern/project/accelerating-novel-antimicrobial-discovery

59 'Water leak detection', Open Quantum Institute, https://open-quantum-institute.cern/project/water-leak

60 G. Alabaster et al., 'White paper 2024: SDG use cases', Open Quantum Institute (2024), https://open-quantum-institute.cern/wp-content/uploads/2024/12/OQI_WhitePaper2024.pdf

61 'OQI Hackathon in a Box', Open Quantum Institute, https://open-quantum-institute.cern/hackathon-in-a-box

62 F. Bargellini et al, 'Intelligence report on quantum diplomacy for the Sustainable Development Goals (SDGs)', Open Quantum Institute (2024), https://open-quantum-institute.cern/wp-content/uploads/2025/03/GESDA_OQI_Intelligence-Report-2024_Final.pdf

63 J.-C. Mauduit and M. Gual Soler, 'Building a science diplomacy curriculum', Frontiers in Education, 5, (2020), https://doi.org/10.3389/feduc.2020.00138

64 New report maps landscape of science for policy and diplomacy education in Switzerland and beyond', Swiss Young Academy (2025), https://en.swissyoungacademy.ch/news/new-report-maps-landscape-of-science-for-policy-and-diplomacy-education-in-switzerland-and-beyond

65 'Global curriculum for Anticipatory Leadership', Geneva Science and Diplomacy Anticipator, https://gesda.global/global-curriculum-for-anticipatory-leadership

66 Social simulations: introduction', Social Simulations, https://socialsimulations.org

67 New quantum game to train future leaders in anticipatory science diplomacy', Geneva Science and Diplomacy Anticipator, https://gesda.global/new-quantum-game-to-train-future-leaders-in-anticipatory-science-diplomacy

68 The Quantum Diplomacy Game', Open Quantum Institute, https://open-quantum-institute.cern/quantum-diplomacy-game