



The Palgrave Handbook of Science Diplomacy

Edited by
Jan Lüder · Martin Wählich

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Editors

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ISBN 978-3-032-29472-2 ISBN 978-3-032-29473-9 (eBook)
<https://doi.org/10.1007/978-3-032-29473-9>

This work was supported by German Academic Exchange Service.

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FOREWORD

In a time marked by deep geopolitical upheaval and rapid technological advancement, science diplomacy plays an increasingly crucial role in shaping international cooperation. As disruptive technologies continue to transform the global landscape, the ability to use science as a bridge between nations has never been more important. Science diplomacy is not only a resource for fostering scientific exchange but also a strategic instrument that actively shapes geopolitical dynamics.

As such, science diplomacy is an integral part of Germany's foreign policy. It strengthens the country's position as a global hub for science and innovation. By promoting international mobility and cooperation, it also contributes to economic prosperity and supports efforts to attract of highly skilled talent.

A key priority is scientific freedom, which is essential for research excellence in Germany and in the European Union. Research and innovation thrive in an environment of openness and security. This is crucial not only for the scientific community but also for the prosperity and resilience of society as a whole.

With stakes as high as these, our systems for funding, conducting, and applying research must adapt to these evolving realities. Transparency, international collaboration, and academic freedom have long been key components of Germany's Science Diplomacy. Research security, risk awareness, and the protection of critical knowledge are principles of responsible science, which have to take their place alongside these established norms.

International cooperation is a cornerstone of Germany's science diplomacy. Supported by organizations such as the German Academic Exchange Service (DAAD), the Alexander von Humboldt Foundation (AvH), and the German Archaeological Institute (DAI), global networks are created that extend beyond scientific exchange and foster long-term partnerships.

Within this framework, the German Centres for Research and Innovation (DWIH) are flagship institutions of Germany's international science diplomacy. Funded by the DAAD with resources from the Federal Foreign Office of Germany, they form a global network of platforms in leading innovation hubs

such as New Delhi, New York, San Francisco, São Paulo, and Tokyo. Acting as interfaces between academia, policy, and industry, they promote dialogue, build trust, and enable cooperation in key technological fields.

The DWIH New York and San Francisco exemplify this role through their targeted science diplomacy initiatives. Their participation in flagship events such as the ASCE Conference on Research Security at Texas A&M University and the Science Diplomacy Summit at Johns Hopkins University in Washington, DC, highlights their engagement at the forefront of transatlantic scientific exchange. Complementing these efforts, the DWIH conduct roadshow formats in close cooperation with the German Embassy in Washington and in collaboration with German science organizations active in the United States—including the DFG, DAAD, Fraunhofer USA, and the Max Planck Society—with a focus on regions beyond established coastal hubs. These activities convene leading stakeholders from science, policy, and civil society, positioning the DWIH as key intermediaries in discussions on research security and innovation policy. Targeted exchanges with political decision-makers, including members of the German Bundestag, further underscore their ability to translate scientific and innovation expertise into informed policy decisions.

Thus, science diplomacy is a strategic tool that goes far beyond the academic landscape. It is an element of global diplomacy that contributes to addressing the most pressing challenges of our time—from promoting research security to supporting the global dialogue on the ethical and political dimensions of emerging technologies.

This handbook will hopefully enrich the global discussion about the role of science in international diplomacy. I congratulate the authors and the DWIH New York for taking this initiative.

Minister of State, German Federal Foreign Office
Berlin, Germany

Serap Güler

FOREWORD

Science has long served as an enduring bridge between societies, cultures, and generations. In an era of profound technological transformation and major global challenges, thinking in a science-based and transnational manner has never been more crucial.

Science and education are key pillars of international understanding. They lie at the heart of *science diplomacy*. As the world's largest organization for the international exchange of students and researchers, the German Academic Exchange Service (DAAD) has played a central role in shaping science diplomacy for over a century. Cross-border academic cooperation builds trust. It helps sustain dialogue and keeps channels of cooperation open. In doing so, it forms lasting networks—even in times of global upheavals and disruptions, as witnessed today through rapid technological advancements.

Funded by the DAAD through resources provided by the German Federal Foreign Office, the German Centres for Research and Innovation (DWIH) serve as prominent platforms for establishing and strengthening such networks. Located in Tokyo, New Delhi, São Paulo, New York, and San Francisco, the DWIH offices function as showcases, networking hubs, and points of dialogue for international stakeholders from science, policy, and industry. In addition, the Center for International Academic Cooperation (KIWi) in Bonn supports German universities in creating sustainable international partnerships.

However, establishing and maintaining these partnerships comes with challenges. In this era of accelerating technological disruption, explored in depth in this volume, international science must unite two different aspects. On the one hand, the international scientific community drives innovation. On the other, it reflects critically on the ethical, political, and social implications of its advances. Breakthroughs in fields such as artificial intelligence, biotechnology, and quantum technologies hold enormous potential for prosperity and sustainable development. Yet, they also raise fundamental questions about democracy, participation, and—in light of national interests gaining importance in science diplomacy—questions of knowledge security.

This *Handbook of Science Diplomacy* was developed under the auspices of the German Center for Research and Innovation DWIH New York. Its foundations were laid during the 2024 flagship event, the FUTURE FORUM “Science Diplomacy in an Era of Technological Disruption”, held at Johns Hopkins University, which brought together leading voices from academia, policy, and science diplomacy practice. The resulting volume demonstrates how science diplomacy is evolving through new actors, networks, and institutions, and how technological change shapes this transformation. The contributions highlight the indispensable role of science diplomacy in tackling the challenges of an interconnected world.

I hope this volume stands as both a testament and a call to action: to strengthen the bridges of knowledge, foster trust across borders, and advance a science diplomacy that meets the challenges of our shared global future.

German Academic Exchange Service (DAAD)
Bonn, Germany

Joybrato Mukherjee

FOREWORD

Science diplomacy, as a concept, has in the past years moved from the periphery to the center of conversations, analyses, and strategies on international academic cooperation. As global challenges seem to become increasingly complex and interconnected, the role of the individual researcher seems to have grown both in terms of significance and scope. Against this backdrop, this volume explores how science diplomacy can foster and sustain collaboration under evolving framework conditions and in an environment increasingly shaped by the growing importance of international scientific cooperation in the face of shared global challenges, on the one hand, and geopolitical competition, on the other. It is a joint effort of the German Center for Research and Innovation (DWIH) New York and its partners on both sides of the Atlantic.

DWIH New York is part of a wider, global network spearheaded by the German Academic Exchange Service (DAAD), itself a longstanding actor and enabler in the field of science diplomacy, celebrating its centennial in 2025. The DAAD's Strategy 2030 positions science diplomacy not as a peripheral activity or a mere outcome, but as a core instrument of international engagement (German Academic Exchange Service 2025). Framed within a “foreign science *realpolitik*” that is driven by pragmatism and on-the-ground facts, the strategy underscores the need to balance opportunity and risk in international academic cooperation. Science diplomacy, here, emerges as both a means of sustaining dialogue across political divides and a mechanism for jointly exploring solutions to global problems. The tools employed to achieve these means are international academic exchange, global networks, expert guidance drawing from many years of experience in shaping multilateral collaboration, strong alumni networks, as well as, not least of all, showcase and matchmaking platforms such as the DWIH.

Backed by a broad alliance of German science organizations, research-driven industry, and institutional partners, the worldwide DWIH network thus illustrates how science diplomacy can be put into practice through sustained engagement across a broad range of partners. By convening researchers, policymakers, industry leaders, and entrepreneurs, each of the five DWIH create

spaces where scientific exchange informs policy and supports innovation, be it in New York, San Francisco, São Paulo, Tokyo, and New Delhi.

Initiatives such as the annual DWIH NY Future Forum, from which this volume emerged, convene stakeholders from across the Atlantic to address shared challenges and demonstrate how science diplomacy not only strengthens transatlantic ties but also translates knowledge into economic and societal impact for the countries involved. Targeted support for startups and research partnerships like the STEP USA University program, run in partnership with the German American Chamber of Commerce (GACC) New York, help foster transatlantic ties between university-based entrepreneurs at an early and crucial stage and create lasting networks in industry and science. And the DWIHs' engagement with multilateral actors including the United Nations, the International Science Council, and UN Global Compact further highlights how science diplomacy contributes to advancing global agendas, while the DWIH network's work on research security, governance, and ethics reflects the growing importance of aligning scientific cooperation with geopolitical realities.

These realities lie at the core of a “foreign science *realpolitik*”. Science diplomacy can be understood in different ways: As a means to advance international scientific collaboration, as a bridge in times of political tension, and as a means to push forward concrete agendas of national importance in an international environment. Within this spectrum, recent publications, including frameworks such as the European Commission's “European Framework for Science Diplomacy” (2025), highlight a shift toward the latter, more interest-driven understanding. Science diplomacy is increasingly seen not only as a form of soft power that promotes mutual understanding but also as a contributor to hard power, supporting technological sovereignty and global influence. As emphasized in recent reports such as the Royal Society and the American Association for the Advancement of Science's (AAAS) “Science Diplomacy in an Era of Disruption” (2025), the field is evolving in response to profound technological, geopolitical, and societal transformations. No longer viewed as inherently benevolent, science diplomacy is increasingly understood as a neutral instrument whose impact depends on how and why it is used. This is important to be aware of, and several contributions to this volume take into account this widely perceived shift.

Despite the evolving backgrounds against which it is seen, science diplomacy still derives its strength from a combination of awareness, responsibility, and the ability to connect actors across borders in pursuit of shared goals. First and foremost, it requires researchers to recognize their role not only as scientists but also as participants in a broader diplomatic ecosystem, one that is increasingly shaped by frameworks such as export controls and research security. Successful large-scale examples, from collaborations aboard the International Space Station to global vaccination partnerships like Pfizer and BioNTech, demonstrate how international teams can align around common objectives and generate global impact that is larger than its individual parts. At its best, science diplomacy in this way becomes a force for cooperation, trust-building, and more equitable outcomes, provided it remains, to quote from another DAAD paper, this one

on collaborating with China, knowledge-based, risk-aware, and conscious of the diverse interests at play. Crucially, its effectiveness depends on equitable partnerships that emphasize capacity building, knowledge sharing, and fair access to innovations (German Academic Exchange Service 2024).

Ultimately, though, science diplomacy is sustained not only by institutions but by people-to-people connections: Relationships among scientists, public health experts, and diplomats that can endure political tensions and serve as vital backchannels for continued cooperation. These personal foundations are not incidental. They are built in shared laboratories, in joint fieldwork, in conference conversations that extend late into the evening, in symposia, networking events, and in the everyday practices of intellectual exchange. Over time, such interactions generate a level of trust that formal agreements alone cannot produce.

In this sense, science diplomacy is not so much a fixed arrangement but a living ecosystem. It is sustained by individuals who move between systems, interpret across institutional cultures, and maintain channels of communication when formal diplomacy slows. To create and foster these networks requires sustained investment: In mobility programs, in fellowship structures, in alumni engagement, in networking platforms and showcase events, in short, in creating the spaces where such trust is built.

It is through this sustained investment, and the enduring scientific network it has fostered, that this publication has come to fruition. On behalf of the entire DWIH New York team, we extend our sincere gratitude to all contributors whose individual expertise has shaped this volume into a collective endeavor greater than the sum of its parts, as well as to our funding partners, the DAAD and the German Federal Foreign Office. The resilience of science diplomacy rests on relationships cultivated over time and sustained collaboratively across generations. We hope this volume will help take stock, look forward, and inspire generations to come.

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Acknowledgements When we first released our call for chapters in 2024, we were unprepared for the breadth of interest in the topic of science diplomacy and emerging technologies in a changing geopolitical world. We are deeply grateful to all the authors and contributors to this volume and thankful for the opportunity to have worked with you over the past two years. Your insights, research, and commitment made this project possible. We want to especially thank William Colglazier and Tim Flink for their leadership in advancing science diplomacy in theory and praxis and their invaluable guidance.

We would like to thank Tabea Kaiser and Benedikt Brisch at the German Academic Exchange Service (DAAD) for supporting this project from its earliest stages of ideation. Our sincere thanks also go to our early readers and anonymous reviewers, whose feedback helped shape the direction of the volume.

This volume was made possible through funding by the German Federal Foreign Office, with coordination by the German Academic Exchange Service (DAAD). We gratefully acknowledge the support of these institutions, with special thanks to Michael Harms, Muriel Helbig, Joybrato Mukherjee, Ursula Paintner, Kai Sicks, Christian Strowa, and Sakine Weikert.

We are also grateful to the many scientists, diplomats, policymakers, and researchers who generously shared their time and expertise. Particular gratitude go to Ona Ambrozaite for making it possible to host the DWIH New York 2024 FUTURE FORUM: “Science Diplomacy in an Era of Technological Disruption” at the Johns Hopkins Science Diplomacy Hub—cofounded by Nobel Laureate Peter Agre and aforementioned JHU alumna Ona Ambrozaite. We are indebted to them for creating the space to meet in person to discuss the emerging chapters and case studies in this volume. We also thank all supporters and participants of the forum and the contributing experts and moderators, especially Ambassador Andreas Michaelis—Ambassador of the Federal Republic of Germany to the United States, Eugene Bae—Director of Technology Policy at the U.S. Department of State, Paul Berkman, Georg Bechtold, Eva Bosbach, Dana Cowlshaw, Sebrina Geier, Christian Haenel, René Haak, Katrin Kohs, and Simone Laessig.

Finally, we extend our sincere thanks to Rebecca Theis for her tireless editing and coordination of the manuscript’s finalization. We are also grateful to Nick Reinert for his careful final review, and to Saskia Ibrom, David Kuerbiss, Julia Helmes, and Geza Schenk for their communication, logistical, and creative support throughout the last two years. Our appreciation finally goes to the team at Palgrave Macmillan and especially Anca Pusca for taking on this volume and for their thoughtful edits, detailed feedback, and support in bringing this volume to publication.

ABOUT THIS BOOK

This handbook examines the transformation of science diplomacy in an era defined by geopolitical rivalry, rapid technological change, and contested global governance. Moving beyond traditional notions of science diplomacy as a cooperative, state-led endeavor, the volume advances a polycentric framework that captures a more complex reality of a fragmented landscape in which authority, expertise, and infrastructure are distributed across states, international organizations, corporations, universities, and transnational networks.

At its core, the book argues that science diplomacy is no longer primarily about fostering collaboration, but about governing the conditions under which collaboration remains possible, legitimate, and resilient. Contributions explore how emerging technologies such as artificial intelligence, biotechnology, and quantum computing intensify competition while simultaneously requiring cross-border cooperation. They also examine how non-state actors, private platforms, and subnational entities increasingly shape agendas, standards, and access to knowledge.

Structured across conceptual, empirical, and forward-looking sections, the handbook combines theoretical innovation with practice-oriented case studies. It highlights key trends including the securitization of science, the rise of new diplomatic actors, and the growing importance of technological infrastructures as sites of power. Throughout, authors interrogate the trade-offs between openness and security, inclusion and control, and innovation and governance.

By reframing science diplomacy as a problem of institutional design and interface governance, this volume offers a timely and rigorous guide for scholars, practitioners, and policymakers seeking to navigate cooperation under conditions of uncertainty, asymmetry, and disruption.

Praise for *The Palgrave Handbook of Science Diplomacy*

“This Handbook on Science Diplomacy is timely and makes an important contribution to current debates and deliberations in a rapidly changing world to realise the hope and opportunity that science brings to ensure a sustainable future for many generations to come. It brings together the voices from an impressive range of scholars and practitioners at the coalface of the intersection of science, technology, diplomacy, and international cooperation.”

—Quarraisha Abdool Karim, *President of the The World Academy of Sciences*

“At the end of the first quarter of the 21st century, science, technology, economic, security and geopolitical interests are more intertwined than ever. In this context, as science and technology undergo fundamental evolution alongside a complex and changing geopolitical landscape, the interaction between science and diplomacy must also evolve. This volume of conceptual and illustrative essays should be of value to both scholars and practitioners of the evolving discipline of science diplomacy.”

—Sir Peter Gluckman, *President of the International Science Council*

“There has never been a more important time to advance science diplomacy. This authoritative volume offers a critical reframe for our times and will provide a vital handbook for the disrupted years ahead.”

—Dame Juliet A. Gerrard, *Professor at the University of Auckland and former Chief Science Advisor to the Prime Minister of New Zealand*

“Scientific knowledge keeps expanding at an ever faster pace, and diplomacy needs to keep up: knowledge has always been a source of power, and in an era of intensifying geopolitical competition, it can lead to new conflicts as well as to deeper cooperation. This handbook is an indispensable guide for all those who want to understand the diplomacy of the future.”

—Jean-Marie Guehenno, *former UN Under-Secretary-General and Arnold A. Saltzman Professor of Political Practice at Columbia University*

“This work makes the powerful case that scientific trust, integrity and collaboration provide a unique foundation for harmonious international relations. The book is rich in examples and learnings from practical experience. It describes success factors that provide a blueprint for individual researchers, science agencies and governments wishing to build enduring bridges through science diplomacy.”

—John Stocker, *former Chief Scientist of Australia and former Chief Executive of the Commonwealth Scientific and Industrial Research Organisation (CSIRO)*

“With statecraft on the decline globally, the Handbook on Science Diplomacy is a timely guide to navigating global fragmentation and technological disruption. It powerfully demonstrates how science diplomacy can advance cooperation, build much-needed trust, and address shared challenges in a highly polarized world.”

—Moneef R. Zou’bi, *Science Advisor to the InterAction Council*

“This is a timely and well-crafted volume that takes seriously how science diplomacy is being reshaped by technological disruption and geopolitical competition. By advancing an analytically innovative polycentric perspective, the editors and contributors recast science diplomacy as a problem of governing distributed authority, expertise, and infrastructure, moving decisively beyond abstract calls for cooperation. It will be an important and widely used reference for scholars and practitioners working at the intersection of science, technology, and diplomacy.”

—Corneliu Bjola, *Professor of Digital Diplomacy at the University of Oxford*

“This handbook is a timely publication. Only a few years ago, science diplomacy promised solutions to global crises such as climate change and pandemics. Today, geopolitical upheavals, above all Russia’s invasion of Ukraine, and technological disruptions driven by AI have posed entirely new challenges to the field. In this context, risk management has become a central academic concern. The chapters of this handbook identify current risks and discuss ways to address them, from ensuring the transparency, reproducibility, and universal validity of scientific knowledge to fostering trust in science and legitimating scientific advice to governments. In essence, this is a matter of redefining the conditions for international scientific cooperation. This handbook will be an essential tool for those wishing to sustain hope in scientific rationality in the face of an emerging martial and confrontational multipolar world order.”

—Carola Sachse, *Professor Emerita of Contemporary History at the University of Vienna*

“In our present moment, reflection and action on the circulation, governance, and engagement of science are not only timely but unavoidable. Science diplomacy’s polyhedral character has deepened into a form of complexity that generates both heightened tensions and significant potential - perhaps even the possibility of contributing to the making of a different future. This handbook contributes to these debates by bringing together a diverse range of voices that attend to the multiplicity of actors and organisations shaping the field.”

—Barbara Silva, *Associate Professor at the Pontifical Catholic University of Chile*

“In an era where global challenges demand creative, cross-border solutions, the Handbook of Science Diplomacy is a welcome, necessary resource for leaders committed to advancing international relationships. This volume offers a timely and rigorous guide to navigating the complexities of science diplomacy, highlighting how strategic partnerships and network-building can drive impactful research and innovation across geopolitical divides. The actionable insights and case studies provided will help institutions to build resilient, inclusive, forward-looking collaborations to address the world’s most pressing issues.”

—Annette Gray, *Interim Vice Provost for Research at New York University*

“This important handbook affirms that science diplomacy is strongest when grounded in political neutrality, methodological rigor, and intellectual independence. It demonstrates how scientists and researchers can contribute constructively to world affairs without compromising the credibility that gives science its public value.”

—Alexander S. Preker, *President and CEO, Health Investment and Financing Director, USA Healthcare Alliance Adjunct Assistant Professor, Columbia University Adjunct Assistant Professor, Icahn School of Medicine at Mount Sinai, New York, Former Chief Economist for Health, World Bank Former Head of Health Investment Policy, International Finance Corporation*

“Geopolitical, social, and technological changes are currently reshaping the relationship between science and politics in the field of international cooperation. This anthology provides a comprehensive overview of the debate surrounding the concept of science diplomacy and offers new perspectives on what science diplomacy can and should be in our multipolar world.”

—Sven Werkmeister, *Director of Strategy at German Academic Exchange Service (DAAD)*

“The international context of science diplomacy has changed dramatically during the past couple of decades, from one of unfettered globalization to one of geopolitical strategic rivalry in a multipolar world of influence and mistrust. This dramatic shift requires a deep rethinking of the objectives, analytical lens, and tools of science diplomacy as well as of the actors engaging in it. This book does exactly that quite skillfully by blending multiple perspectives and a wide array of themes. It is a must read for those interested in the new style of hardened polycentric science diplomacy in an era of technological disruption.”

—Nicholas Vonortas, *Associate Dean of Research at the Elliott School of International Affairs, The George Washington University*

“A great paradox of our moment is that advances in science and technology, and our responses to them, have made international cooperation both more urgent and more fragile. The shared epistemic ground we have sought is fractured and authority has been redistributed in ways that resist traditional governance. This book confronts our predicament with unusual clarity. By reframing science diplomacy not as idealized bridge-building but as practical interface governance—asking how the linkages among infrastructure, authority, and expertise can be designed to keep cooperation legitimate and resilient—it provides material to create a new framework for action. When the credibility of claims, methods, and risk frames is itself contested, new conditions for cooperation must be constructed with sober acceptance of a multiplicity of rival perspectives and aims. This handbook shows us how.”

—Jeff Seul, *Lecturer on Law, Harvard Law School, Lecturer on the Practice of Peace, Harvard Divinity School, Co-chair, Peace Appeal Foundation, Partner and Chair, Technology and Telecommunications Industry Sector Group, Holland & Knight LLP*

“I have to say this collection is like a work of art – insightful, deep and comprehensive. At last someone has tackled a complex subject and made it understandable. It fills a significant gap in our collective knowledge.”

—Charles Landry, *International Adviser on the Future of Cities; Author and Speaker; Founder of Comedia; Co-founder of the Creative Bureaucracy Festival; Developer of the “Creative City” concept*

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ABBREVIATIONS

4IR	Fourth Industrial Revolution
AAAS	American Association for the Advancement of Science
AASSA	Association of Academies and Societies of Science in Asia
AfSA	African Space Agency
AGI	Artificial general intelligence
AI	Artificial intelligence
AISI	AI Safety Institute
AI Act	Artificial Intelligence Act (European Union)
AIGC	AI Governance Clinic
ALCE	Latin American and Caribbean Space Agency
APRSAF	Asia-Pacific Regional Space Agency Forum
APSCO	Asia-Pacific Space Cooperation Organization
AR	Augmented reality
ASADI	African Science Academy Development Initiative
ASOMPS	Asian Symposium on Medicinal Plants and Spices
ATM	Automated teller machine
AZ	Arizona
BAAS	British Association for the Advancement of Science
BIS	Bureau of Industry and Security
BKC	Berkman Klein Center for Internet & Society at Harvard University
BMWK	German Federal Ministry for Economic Affairs and Climate Action
BOSTID	Board on Science and Technology for International Development
BRI	Belt and Road Initiative
BRICS	Brazil, Russia, India, China, and South Africa
BSEL	Berlin School of Economics and Law
BWC	Biological Weapons Convention
CCP	Chinese Communist Party
CD	Conference on Disarmament
CEIMIA	The Montreal International Center of Expertise in Artificial Intelligence
CERN	European Organization for Nuclear Research
CGIAR	Consultative Group on International Agricultural Research
CHIPS	Creating Helpful Incentives to Produce Semiconductors

COMNAP	Council of Managers of National Antarctic Programs
COP	Conference of the Parties
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
COVID	Coronavirus disease
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWC	Chemical Weapons Convention
DAAD	German Academic Exchange Service
DfS	Diplomacy for Science
DIAS	Data and Integration and Analysis System
DLR	German Aerospace Center
DRAM	Dynamic Random-Access Memory
DSA	Digital Services Act
DUV	Deep ultraviolet
ECAFE	Economic Commission for Asia and the Far East
EDA	Electronic Design Automation
EDMO	European Digital Media Observatory
EIGE	European Institute for Gender Equality
ELDO	European Launcher Development Organisation
EPFL	Federal Institute of Technology in Lausanne
ESA	European Space Agency
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
ESRO	European Space Research Organisation
ETDA	Electronic Transactions Development Agency of Thailand
EU	European Union
EUV	Extreme ultraviolet
FACS	Federation of Asian Chemical Societies
FAID	Framework for AI Diffusion
FAOBMB	Federation of Asia and Oceanian Biochemists and Molecular Biologists
FAPS	Federation of Asian Polymer Societies
FCDO	Foreign, Commonwealth & Development Office
FDPR	Foreign Direct Product Rule
FFT	Fast Fourier Transform
FÖPS	Research Institute for Public and Private Security (Berlin School of Economics and Law)
G7	Group of Seven
GCO	Global Climate Observing System
GDPR	General Data Protection Regulation
GESDA	Geneva Science and Diplomacy Anticipator
GINs	Global Innovation Networks
GIS	Geographic Information Systems
GISAID	Global Initiative on Sharing All Influenza Data
GIZ	German International Cooperation Society
GPAI	Global Partnership on AI
GPAI	General purpose artificial intelligence
GPS	Global Positioning System
GPU	Graphics processing units
GSNs	Global Science Networks

GVCs	Global value chains
HAIP	Hiroshima AI Process
HBM	High-bandwidth memory
HE	Higher education
HLAB-AI	High-Level Advisory Body on Artificial Intelligence
IAP	InterAcademy Panel
IASC	International Arctic Science Committee
IAEA	International Atomic Energy Agency
IASEAI	International Association for Safe and Ethical AI
IATT	Inter-Agency Task Team
ICANN	Internet Corporation for Assigned Names and Numbers
ICAO	International Civil Aviation Organization
ICEGOV	International Conference on Theory and Practice of Electronic Governance
ICEP	International Collaboration and Exchange Program
ICRC	International Committee of the Red Cross
ICT	Information and Communication Technology
IDRC	International Development Research Center
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFFT	Inverse Fast Fourier Transform
IHL	International Humanitarian Law
IIASA	International Institute for Applied Systems Analysis
ILRSCO	International Lunar Research Station Cooperation Organization
INGSA	International Network for Government Science Advice
INRIA	National Institute for Research in Digital Science and Technology
IoME	Internationalization of Medical Education
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IR	International relations
ISC	International Science Council
ISRO	Indian Space Research Organization
ISS	International Space Station
ISU	Implementation Support Unit
ISTC	Institute for Scientific and Technological Cooperation
ITU	International Telecommunication Union
IWPR	Institute for Women's Policy Research
JAXA	Japan Aerospace Exploration Agency
JHSDG	Johns Hopkins Science Diplomacy Hub
JICA	Japan International Cooperation Agency
JRC	Joint Research Centre
LASTRO	Laboratory of Astrophysics
LLM	Large Language Model
LOAC	Law of Armed Conflict
MBRSC	Mohammed bin Rashid Space Centre
MDGs	Millennium Development Goals
MEA	Ministry of External Affairs (India)
MENA	Middle East and North Africa
METI	Ministry of Economy, Trade, and Industry

MFAs	Ministries of Foreign Affairs
MIC	Ministry of Internal Affairs and Communication
MIT	Massachusetts Institute of Technology
MoU	Memorandum of Understanding
MUST	Multiplexed Survey Telescope
MWM	Million Women Mentors
NAIAC	National Artificial Intelligence Advisory Committee
NASA	National Aeronautics and Space Administration
NSDD	National Security Decision Directive
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
OIA	Office of International Affairs
OST	Outer Space Treaty
PEPFAR	President's Emergency Plan for AIDS Relief
PLA	People's Liberation Army
PPWT	Treaty on the Prevention of the Placement of Weapons in Outer Space
PRC	People's Republic of China
PRI	Polar Research Institute (Türkiye)
PTWS	Pacific Tsunami Warning System
QIST	Quantum Information Science and Technology
R&D	Research and Development
RC Trust	Research Center Trustworthy Data Science and Security
S&T	Science and Technology
S4D4C	Using Science for/in Diplomacy for Addressing Global Challenges
SAPEA	Science Advice for Policy by European Academies
SCAR	Scientific Committee on Antarctic Research
SD	Science Diplomacy
SDCfA	Science Diplomacy Center for Africa
SDG	Sustainable Development Goals
SDI	Strategic Defense Initiative
SDSS	Sloan Digital Sky Survey
SESAME	Synchrotron-light for Experimental Science and Applications in the Middle East
SKA	Square Kilometre Array
SME	Semiconductor Manufacturing Equipment
STAS	Science and Technology Adviser to the US Secretary of State
STEM	Science, Technology, Engineering, and Mathematics
STI	Science, Technology, and Innovation
STN	Science and Technology Network
T3	Turkish Technology Team Foundation
TDGI	Tech Diplomacy Global Institute
TFM	Technology Facilitation Mechanism
TSMC	Taiwan Semiconductor Manufacturing Company
TTC	EU-US Trade and Technology Council
TU	Dortmund Technical University Dortmund
TUA	Turkish Space Agency
TÜBİTAK	Scientific and Technological Research Council of Türkiye
TÜSEB	Health Institutes of Türkiye

UAE	United Arab Emirates
UA Ruhr	University Alliance Ruhr
UAS	Universities of Applied Sciences (Germany)
UHU	United Help Ukraine
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNITAR	United Nations Institute for Training and Research
UNOOSA	United Nations Office for Outer Space Affairs
UNOCC UN	Operations and Crisis Centre
UNU	United Nations University
UNU-CRIS	United Nations University – Institute on Comparative Regional Integration Studies
USA	United States of America
USAID	United States Agency for International Development
VR	Virtual reality
WEF	World Economic Forum
WHO	World Health Organization
YÖK	Council of Higher Education (Türkiye)
YTB	Presidency for Turks Abroad and Related Communities

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Analytical Lens and Decision Tools
for Science Diplomacy in an age
of disruption

Analytical Lens and Decision Tools for Science
Diplomacy in an Age of Disruption



Polycentric Science Diplomacy in an Age of Disruption

Jan Lüdert and Martin Wählich

1 INTRODUCTION

Science diplomacy (SD) is being redefined. In an era of accelerating technological change, geopolitical disruptions, and of renewed pressure on multilateral institutions, SD has become a high-stakes instrument for managing interdependence under conditions of contestation and competition (Flink et al. 2025; Nature 2025). Once cloaked in idealism and the language of cooperation, it now operates in an environment shaped by strategic rivalry, contested governance, and the weaponization of knowledge (Farrell and Newman 2019; Rungius and Flink 2020; Ruffini 2020a). The central question is no longer how to foster collaboration, but under what conditions, by whom, and to what end. A useful way to describe the shift is from science diplomacy as channel-building to science diplomacy as governance under uncertain conditions; which entails designing rules and norms, infrastructures, and fostering legitimacy that make collaboration workable when trust is partial and power asymmetric.

This handbook's main impetus is to respond to a simple empirical observation: SD is no longer confined to a recognizable diplomatic center, nor reducible to cooperation as a default norm. Its practice is increasingly defined

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upstream by both public and private actors. These actors exert influence through funding conditions, research security protocols, standards processes, and the control of critical infrastructures. Through substantive chapters and praxis-grounded case studies, this volume advances a core claim. SD is today best understood as *polycentric*, that is, as a field of multiple, overlapping centers of authority and expertise operating across states, regional blocs, international organizations, universities, cities, firms, foundations, professional societies, and standards bodies (Szkarłat et al. 2025). Polycentricity is a response that can create resilience through redundancies and multiple channels of engagement (Ostrom et al. 1961; Ostrom 2010). Yet it can also concentrate power in indirect and less accountable ways, as influence is exercised through various channels of funding, standards, platforms, and access rather than through classic diplomatic negotiation and state-centric decisions alone (Mattli and Büthe 2003; Büthe and Mattli 2011; Yates and Murphy 2019).

We posit that framing SD as polycentric governance helps explain why familiar categories, science *in* diplomacy, diplomacy *for* science, and science *for* diplomacy, are still necessary yet insufficient (Flink and Schreiterer 2010; Kaltofen and Acuto 2018). The tripartite typology that has long defined SD remains a useful orientation, but it presumes a relatively legible diplomatic center from which its functions and practices radiate. In the present environment, authority is less neatly organized but dispersed and contested, because decisions that determine the scope of cooperation are routinely taken upstream of formal diplomacy, in research security policies, procurement and export controls, platform governance, standards-setting, and the design of scientific infrastructures (Plantin et al. 2018; Zúñiga et al. 2024). In other words, the propositions of “in” and “for” inherent to the tripartite SD typology can be operationalized via a focus on polycentric governance. Such a move clarifies variations in the core functions of SD in an era of disruption in terms of actors’ inclusion and exclusion as well as their location, interest, and purpose within overlapping polycentric governance structures.

While we retain the classic tripartite typology (science in diplomacy, diplomacy for science, science for diplomacy) as a functional orientation, we treat it as insufficient for locating where and how consequential decisions are now made. Complementing it, Flink and Schreiterer’s access-influence-promotion typology helps clarify the objectives that different actors pursue when they invoke science diplomacy (Flink and Schreiterer 2010). A polycentric lens is thus an integrating approach to establish empirically how SD functions and its objectives are realized through dispersed sites of authority, expertise, and infrastructure.

Polycentricity explains what changes. SD has, of course, always been entangled with power politics; even if less openly. What is new is the intensity, speed, and visibility of such entanglements. Disruptive technologies such as AI, quantum computing, synthetic biology, and climate engineering are not merely scientific fields; they are transformative capabilities for states that come with blurry civilian–military boundaries, rapid innovation cycles, as well as deep and

uncertain societal consequences (Funtowicz and Ravetz 1993; Stilgoe et al. 2013). At the same time, geopolitical polarization and techno-national strategies are fragmenting the multilateral fabric that enabled scientific cooperation over the last 80 years or so. SD is therefore pulled in two directions at once; it is more necessary because today's challenges require cross-border and technical expertise and cooperation, and more contested because science and technology now sit at the center of economic and security competition between states and corporate actors vying to determine their place in the multipolar world that is currently forming (Ruffini 2020b).

To be clear, contributions in this volume do not treat SD as inherently benevolent, nor as an autonomous mechanism with intrinsic values. Instead, authors examine science diplomacy as a repertoire of practices and narratives deployed by states, universities, firms, foundations, professional societies, and international organizations, often with divergent objectives and unequal capabilities. Where chapters make normative claims, they do so explicitly and conditionally, and they foreground the institutional trade-offs involved in sustaining cooperation under conditions of competition, securitization, and contested legitimacy.

2 POLYCENTRIC SCIENCE DIPLOMACY: AUTHORITY, EXPERTISE, AND INFRASTRUCTURE

In our framework of polycentric SD, contributors specify throughout the volume that outcomes are increasingly determined by the interaction of three dimensions: *authority*, *expertise*, and *infrastructure* (Star and Ruhleder 1996; Bütte and Mattli 2011). These are not new ingredients to SD, but they have become primary determinants where power is exercised and contested, often outside classic diplomatic arenas and at much higher speed of change and dislocation.

First, *authority* refers to legitimate rule and norm setting; a recognized capacity to define the terms of participation and compliance that others treat as binding. In contemporary SD, authority is exercised through eligibility criteria, research security rules, procurement constraints, standards processes, and access restrictions, partnership design, and standard-setting norms. These mechanisms define a menu of options for collaboration long before any memorandum of understanding is drafted or any minister shakes hands finalizing agreements (Mattli and Bütte 2003; Bütte and Mattli 2011). Authority, moreover, is more often than not located outside public institutions with research on AI or synthetic biology, for instance, being predominantly conducted by corporations or startups and no longer driven by universities whose delegated authority depends on government signals and funding streams. Authority is thus principally concerned with *who* drives scientific innovations under *what* private or public institutional logics.

Second, *expertise* is the ability to define reality (Carraro 2025). Expertise is not simply technical competence or evidence-based science advice but

encompasses how experts are imbued with forms of legitimacy: who counts as credible, which methods are treated as authoritative, how uncertainty is framed, and whether advice is producing public goods or serves actor's narrow interests. In short, we view expertise as a relational and contested concept between audiences (e.g. policymakers, scientists, epistemic communities, publics). In polarized information environments, compounded by pandemic politics as well as uncertainties surrounding new technologies, scientific advice is under strain, and the interactions of SD between scientific evidence and political interests becomes more porous (Lüdert 2024).

Third, socio-technical *infrastructure* is the locale and hardware that can enable or disable the proper functions of SD. Infrastructure includes data centers, chips, cloud platforms, research networks, and protocols, as well as less visible capacities such as evaluation and auditing tools, multilingual access, and protected spaces for collaboration (Star and Ruhleder 1996; Plantin et al. 2018). If science diplomacy fails to govern the rules of access and terms of engagement for these infrastructures, their owners will effectively govern the field. By controlling these assets, they dictate who participates, what can be independently verified, and where dependencies become locked into critical pathways (Jansen et al. 2023). In this sense infrastructure is inextricably linked to issues of sovereignty and states' capacities over various strategic science and research infrastructures vis-à-vis other states and corporate actors.

Taken together, these three dimensions move SD from an image of idealized 'bridge-building' to a practical design problem that seeks to answer: how to structure pragmatic conditions and mechanisms by which cooperation remains possible, legitimate, and resilient. Crucially, these dimensions rarely operate in isolation but are inherently synergistic. Infrastructures increasingly produce authority by defining pathways of participation and compliance; authority in turn allocates and restricts infrastructure through funding rules, research security policies, procurement, and export controls; and expertise legitimizes (or delegitimizes) both, by determining which claims, methods, and risk frames count as responsible or credible. This handbook therefore, treats polycentric SD as *interface governance*. The practical exercise of SD actors involved in designing, contesting, and stabilizing the linkages among multiple centers, so that distributed power does not simply harden into opaque control via access, interoperability, and dependency.

3 WHY POLYCENTRIC SCIENCE DIPLOMACY, AND WHY NOW

Our proposed polycentric turn in the scholarship and practice of SD is evident and, as such, empirically measurable in the institutional responses under way (Flink and Rüffin 2019). Scientific academies and professional associations are revisiting how science diplomacy is framed and practiced. The Royal Society and AAAS, remain a key reference point, even as technological disruption and geopolitical competition have reshaped the wider policy context in which science diplomacy operates (Royal Society and AAAS 2025; European Commission

2025). In parallel, the European Union has embedded research and innovation more explicitly—under the banner of SD—into its external action and geopolitical strategy, seeking to balance openness with strategic autonomy and research security (European Commission 2021; Csernatoní 2022; Steinbach 2023). The United Nations, meanwhile, has strengthened science–policy interfaces for digital and emerging technologies through institutional reforms and high-level stakeholder processes (United Nations 2023).

This flurry of institutional activity underscores a basic empirical reality as there is no single universal or global science diplomacy. There exists, instead, a crowded governance landscape in which *authority*, *expertise*, and *infrastructure* are negotiated across multiple contested centers, from national security reviews and research grant conditions to standards consortia, platform governance, and university partnerships (Kaltöfen and Acuto 2018; Legrand and Stone 2018). Polycentricity is therefore not a theoretical hypothesis; it is an observable *modus operandi* of science diplomacy in an age of disruption and fragmentation. Polycentricity is not a single governance template. It rather describes a set of arrangements whose feasibility varies by sector, region, and resource constraints. What stabilizes cooperation in one space may not transfer to another; what works in highly resourced innovation systems may not be available elsewhere. That is why the handbook emphasizes comparative diagnosis and design trade-offs rather than universal prescriptions.

4 TRENDS RESHAPING THE FIELD OF SCIENCE DIPLOMACY

Building on our earlier analysis of SD in a fragmented world, this edited volume essentially highlights five interlinked trends that explain the changing landscape and takes to heart the need to empirically substantiate a polycentric approach (Flink et al. 2025).

First, it accounts for geopolitical polarization and the securitization of science. This is due to the fact that science, technology, and innovation (STI) have shifted from relatively insulated cooperative domains to more securitized and national interest driven competitive arenas. Collaboration is now filtered through trust deficits, investment screening, export controls, and strategic competition to bind and expand critical capabilities (Farrell and Newman 2019; Luo and Van Assche 2023). Techno-national policies, illustrated by the US CHIPS and Science Act and China’s Made in China 2025 strategy, condition what forms of collaboration are permissible and where dependencies are tolerated (Flink et al. 2025).

Second, it accounts for emerging technologies as a governance frontier. Innovation cycles, especially in AI, biotechnology, and elsewhere move faster than diplomatic, legislative, and regulatory cycles. Legislators and policymakers struggle to keep pace in domains where the civilian–military boundary is blurred and uncertainty is high. Dual-use may indeed become a misnomer that holds little significance for tomorrow’s governance models. This creates a serious structural mismatch whereby rulemaking is reactive, slow and fragmented,

while technical change is uncertain, rapid, and transnational (Guston and Sarewitz 2002; Stilgoe et al. 2013).

Third, it focuses on the rise of non-state and private actors. Firms, foundations, and transnational networks increasingly set SD agendas, fund research programs, and shape norms and standards next to traditional actors, networks, and institutions in academia, funding agencies, and science ministries (Abbott and Snidal 2009; Büthe and Mattli 2011). The influence of these ‘new kids on the block’ can fill gaps left by under-resourced states and universities, but they also raise legitimacy and accountability concerns, especially when control over data, platforms, and intellectual property becomes a lever of geopolitical influence. Take, for instance, the role of Starlink navigation in nation state conflict and war (Spencer and Goedemans 2026).

Fourth, it contributes to emerging subfields of science diplomacy, including PeaceTech and DiploTech. PeaceTech refers to the use of digital tools and technological innovation to support conflict prevention, peacebuilding, and crisis response, while DiploTech describes the use of technology within diplomatic practice itself. Technology is not only something diplomacy governs; it is also something diplomacy uses. Tools for early warning, translation, remote sensing, and negotiation support can widen access, participation, and institutional capacity, while also introducing new risks related to inequity, surveillance, coercion, and asymmetric dependence.

Fifth, it makes a case for open science as resilience infrastructure. COVID-19 showed that openness can accelerate problem-solving and strengthen resilience at the science-policy-society interface. Yet unequal digital infrastructure, data access, language barriers, and tensions over intellectual property and data sovereignty, to name a few, can turn ideals of openness into yet another channel of uneven distribution of benefits and risks (Hess and Ostrom 2007; Leonelli 2022). UNESCO’s Recommendation on Open Science, we trust, provides a global normative reference point for treating open science as a public good that can improve evidence-based policymaking (UNESCO 2021).

These five trends, as the volume’s chapters will expand, converge on a shared implication; science diplomacy is about governing the *conditions* of knowledge production and exchange, rules of access, architectures of interoperability, and the legitimacy of expertise, rather than solely about facilitating collaboration within an unstable multilateral order (Farrell and Newman 2019; Plantin et al. 2018; Büthe and Mattli 2011).

Read together, these trends also reveal a shift in what the unit of action in science diplomacy is. These can include default settings for data sharing, thresholds for compute access and export licensing, procurement requirements, and the governance of research platforms. In a polycentric science diplomacy environment, such choices influence who can participate in collaboration, who can verify claims, who can escape dependency, and whose expertise becomes relevant. Seen in this light, the politics of science diplomacy lies not only in high-level agreements, but in the institutional design of the infrastructures, rules, and standards through which cooperation is organized and power is distributed.

Analytically, contributions of the volume converge on a distinguishable governance pattern that redefines the evolving field of science diplomacy. Geopolitical polarization and securitization shift authority through new security rules and strict boundaries on permissible collaboration, while the speed of emerging technologies destabilizes traditional expertise and increases reliance on fast-moving technical gatekeepers. Simultaneously, the rise of non-state actors relocates authority and infrastructure into private platforms and funding streams, just as PeaceTech and DiploTech embed digital infrastructure directly into diplomatic practice. Finally, the move toward open science turns the ideal of openness into a practical, infrastructural question of who can truly access, verify, and benefit from shared knowledge and scientific discovery. This is the empirical core of the polycentric claim as science diplomacy outcomes are produced where authority, expertise, and infrastructure are configured.

5 WHAT THIS HANDBOOK CONTRIBUTES

This handbook examines SD under conditions of rapid technological and geopolitical disruption through a combination of conceptual scholarship and practice-based case studies. It treats science diplomacy as interface governance capacity; a set of repertoires, institutions, and tools that, to be effective, must remain open enough for polycentric positioned actors and agents to enable discovery and cooperation, while being resilient enough to withstand coercion, misinformation, and strategic dependency. Rather than assuming SD as inherently benevolent or neutral, the contributions surface the power dynamics that run through collaboration, the legitimacy challenges facing expert advice, and the infrastructures that make, or break, meaningful access and participation (Lüdert 2024).

A polycentric lens shifts attention from an either/or dichotomy on whether to cooperate or not to probing intentional design questions that determine how cooperation actually works and can be maintained in a fragmented environment. Authors in the volume approach these by asking: How are partnerships structured, and who benefits from their terms? Who sets norms, rules, and standards to establish robust compliance pathways, and with what accountability? Which infrastructures enable verification, interoperability, and trusted exchange, and which lock actors into asymmetric dependence? Where do capabilities exist to audit systems, evaluate risk, and exit dependencies without losing access to knowledge or markets? Answering these questions is central to maintaining both cooperation under conditions of competition in a world where sovereignty increasingly functions as a capability problem (Lüdert 2022).

6 HOW THE HANDBOOK IS ORGANIZED

Divided into three parts, this handbook develops polycentric science diplomacy as both an analytical lens and a practical agenda. It navigates an era of disruption where authority, expertise, and infrastructure are distributed across states,

cities, firms, and platforms. At its core the contributions probe a recurring dilemma: how to sustain cooperation amidst intensified competition, securitization, and contested legitimacy.

The first section develops a conceptual framework, offering an analytical entry point and exploration of evolving definitions, scope conditions, and theoretical underpinnings of science diplomacy in the context of new technologies and their transformative impact in a changing geopolitical environment. Authors examine the role of diplomacy in shaping scientific agendas, the dynamics of international collaboration in technological research and development, and the ethical as well as normative considerations surrounding the use of emerging technologies in a global diplomatic context. The section equips readers with a diagnostic vocabulary for a world in which science diplomacy is no longer anchored in a single diplomatic center. Across these chapters, polycentricity is treated as an empirical condition that can be mapped. Helping to unearth where authority sits (mandates, funding, security rules), how expertise becomes legitimate (boundary work, uncertainty, trust), and which infrastructures enable or foreclose cooperation (platforms, standards, supply chains). The central takeaway is that SD today is best approached as decision-making under fragmentation, not as a choice between cooperation or closure but a structured assessment of which channels remain viable, legitimate, and resilient, and what kinds of safeguards are required when cooperation is politically exposed and inherently uncertain.

The second section focuses on the key actors, institutions, and networks involved in science diplomacy, offering case studies that apply the conceptual framework developed in the first section. It demonstrates practical realities, trends, and the application of science diplomacy in various domains, including AI, quantum computing, biotechnology, space exploration, cybersecurity, and other cutting-edge technologies. Through detailed analysis of successful initiatives and the challenges faced by different stakeholders, this section takes stock of current developments and identifies best practices that inform the intersection of science diplomacy with these new technologies. Authors show that polycentric SD is sustained, or in some cases being undermined, by the quality of intermediaries and interface institutions. Contributors capture the role and relevance of professional societies, hubs, technology envoys, city labs, universities, and inclusion networks that translate between communities that do not share incentives, timelines, or risk tolerances. The chapters collectively highlight a practical insight in so far as effectiveness in polycentric SD depends less on who speaks for science than on how convening power is organized, how mandates are defined, conflicts of interest managed, participation widened, and credibility maintained when authority is dispersed across public and private actors. The takeaway is that legitimacy is not an add-on; it is a capability that determines whether cooperation survives stress.

The final section synthesizes insights to explore future prospects and emerging trends in science diplomacy. By presenting visionary perspectives, contributions consider how new technologies are shaping the next era for international

relations, diplomacy, and scientific cooperation. Authors also delve into the broader implications for global governance, seeking to understand how science diplomacy harnesses new technologies to address pressing global challenges. Ultimately, the final section underscores various interdisciplinary approaches and highlights the transformative power of science diplomacy in advancing the betterment of humankind. This part also treats frontier domains as stress tests for polycentric governance. Cases reveal where authority, expertise, and infrastructure collide most sharply, because commercialization, securitization, and standards competition compress decision time and intensify the stakes of dependency. The chapters do not assume that more cooperation is always preferable; they instead surface the design question that recur across SD domains on how to preserve verification, interoperability, and risk-aware openness while retaining the ability to pause, contest, or exit arrangements that become coercive or unsafe. The main takeaway of the section is forward-looking but concrete as the future of SD will be shaped by who can build credible options, including technical, institutional, and political ones, for collaboration to continue without capture.

Given the inherently praxis-oriented nature of science diplomacy, all three sections of the volume consist of both substantive chapters and short case studies. To guide the reader through a long list of contributions, the volume is organized around a single through-line in so far as polycentric SD in our view is governed upstream, through rule-setting, standards, infrastructures, and legitimacy, before it becomes visible as diplomacy. The chapters speak to one another across themes and regions via recurrent insights and dilemmas; speed versus accountability; openness versus security; inclusion versus gatekeeping; and resilience versus dependence. What varies is their sectoral context; what travels across them is the governance problem of designing interfaces among multiple centers so that cooperation remains possible without reverting to either naïve openness or coercive closure.

We begin with unpacking SD and conceptual tools for decision-making under fragmentation, where openness is no longer a default, and where choices about engagement, restraint, or withdrawal must be made under uncertainty. Krishna Ravi Srinivas introduces the concept of Science Diplomacy 2.0, moving beyond state-led frameworks to incorporate the significant authority and infrastructure of technopoles, such as global big tech firms, cities, and non-state actors. Srinivas argues that addressing the governance of disruptive technologies like AI requires an inclusive, multi-stakeholder approach that balances national interests with the practicalities of a fragmented, data-driven world. Jérôme Duberry and Lyse Langlois argue that science has shifted from being a strategic resource to a central arena of geopolitical contestation, where states compete over epistemic governance; the power to define what knowledge is considered credible and valid. By comparing securitized models of the United States, China's pursuit of technological autonomy, and the EU's conditional cooperation model, the authors demonstrate how political priorities actively structure research agendas and enable institutional trust. Tim Flink proposes a

pragmatic heuristic for science diplomacy based on Albert O. Hirschman's Exit, Voice, and Loyalty model to help practitioners navigate an era of intensifying geopolitical rivalry. He argues that traditional, idealistic frameworks are insufficient for managing the risks associated with dual-use technologies and asymmetric cooperation. Sercan Sever and Armin Grunwald dissect how technological disruption is defined by compounding uncertainties. The unpredictable nature of technological outputs and the unknown societal consequences of such uncertainties, they argue, require adaptive principles for science diplomacy to remain resilient. Finja Isabel Augsburg explores the evolving role of scientific uncertainty further, and as a central issue in climate change science diplomacy. She argues that while uncertainty, stemming from knowledge gaps, technical limitations, and lack of consensus, is often viewed as a hurdle, it increasingly acts as a catalyst that facilitates international collaboration and prompts policy responses. Leocadia Díaz Romero provides an overview of transformations of science diplomacy through a focus on digital diplomacy, where technology serves as both a medium and a strategic objective. She highlights how digital tools, ranging from virtual embassies and social media platforms, to data embassies redefine diplomatic norms, particularly in crisis management and public engagement of SD. The section, taken together, demonstrates that navigating technological disruption requires a pragmatic SD framework that reconciles distributed authority with contested expertise. By leveraging the infrastructure of collaboration, these contributions provide conceptual tools to manage SD in a fragmented world where innovation, security, and diplomacy are inextricably linked.

The second part shifts from concepts to the ecosystems that structure SD from intermediary organizations, institutional designs, and leadership practices that can create or fail to create legitimate interfaces among multiple centers of authority. George Salter examines the organizational challenges Ministries of Foreign Affairs (MFAs) face when creating the role of the tech diplomat. The chapter posits that for tech diplomacy to be effective, MFAs must move toward organizational complexification. Bopha Roden et al. demonstrate that professional societies are essential intermediaries in science diplomacy, providing the practical will and credible expertise necessary to translate scientific knowledge into global policy. Using historical and contemporary insights, they illustrate how these organizations operate in various SD domains. Sofie Schönborn, Armando Guio Español, and Urs Gasser present the Global Network of Internet & Society Centers (NoC) as a case for academic-led science diplomacy. They argue that by operating as an informal, decentralized network of networks, NoC bridge the gap between scientific research and global policy. Elmer William Colglazier provides a comprehensive historical and critical analysis of American science diplomacy, tracing the trajectory of US efforts to bolster S&T capacity in emerging nations from the 1970s to the current disruptions of 2026. He argues that while the United States was a foundational leader it is currently reshaped. Christian E. Rieck examines the shifting roles of state and private actors in driving technological disruption, highlighting a persistent

mismatch where state-funded research often fails to reach effective policy or result in market uptake. Rieck argues that while traditional Big Science projects (e.g. CERN, NASA) pioneered historical breakthroughs, the agility and deep pockets of private tech giants now challenge the limits of government steering. S. Ayse Kadayifci-Orellana and Derya Buyuktanir Karacan explore how science diplomacy can be a transformative tool for empowering women in STEM, particularly within emerging economies facing the disruptive effects of automation and AI. Evelina Santa-Kahle, Mireille Guyader, Giusi Condorelli, Ona Ambrozaite, Kerstin Hildebrandt-Abdikarim, and Claire Chen present the Women in Science Diplomacy Association (WiSDA) as a critical intervention to rectify the long-standing gender imbalances in global policy and research. Ona Ambrozaite presents the Johns Hopkins Science Diplomacy Hub as an institutional model that merges scientific inquiry with diplomatic action. Launched in 2023 in Washington, D.C., the Hub acts as a strategic platform on issues such as AI, quantum information science, and global health regulation. Hilke Marit Berger and Gesa Ziemer present City Science Labs (CSL) as platforms for science diplomacy that mediate between entrenched political fronts and antagonistic urban needs. By examining the German city of Hamburg's response to the 2015 refugee crisis and current renewable energy planning, the authors illustrate how digital twins and urban data platforms facilitate multi-stakeholder deliberation. Myriam Dunn Cavelty, Leo Eigner, Sascha Langenbach, and Andreas Wenger present transdisciplinary co-creation as a replicable model for bridging the structural divide between scientific research and international policymaking. Drawing on a flagship partnership between ETH Zürich and the United Nations, the authors argue that science diplomacy must move beyond high-level dialogue toward a three-stage operational cycle of co-design, co-production, and co-implementation. Ekkehard Strauss presents German Universities of Applied Sciences (UAS) as a unique model for science diplomacy. By prioritizing practical relevance and employability, UAS institutions foster connections with public administration and private industry. Anette Wu presents the International Collaboration and Exchange Program (ICEP GLOBAL) as a model for intentional science diplomacy within the health professions. The program leverages digital platforms to connect over 750 medical students annually across 40+ schools on five continents. Nikita Lin identifies art-science diplomacy through a case study of the Cosmos Archaeology exhibition—a collaboration between the Swiss Federal Institute of Technology in Lausanne (EPFL) and the Shanghai Astronomy Museum. Lin analyzes how Swiss science diplomats use immersive media and computational museology. The second section, overall, demonstrates that polycentric SD rises and falls with institutional craftsmanship. The ability to convene actors across sectors, translate between communities, and embed inclusion and integrity into SD mandates, norms, leadership practice, and organizational responses.

The third part looks forward to frontier domains where polycentric science diplomacy is most visible, and often most contested, because governance is stretched across security concerns, commercialization, standards, and societal

consequences that are unforeseeable. Marcus D. Weller argues that AI has fundamentally altered the geopolitical landscape, necessitating a shift from traditional two-dimensional diplomacy to a three-dimensional game-theoretic framework where AI acts as a quasi-autonomous third meta-actor. He posits that in this new era of AI nonlinear risks are introduced that exceed traditional cognitive modeling. Christian Neubacher argues that early AI science diplomacy has remained primarily values-driven, successfully establishing shared taxonomies through bilateral efforts like the EU-US Trade and Technology Council while multilateral UN initiatives remained largely declaratory. He posits that the rapid pace of technological innovation and intensifying geopolitical competition continue to outpace regulatory frameworks and diplomatic coordination efforts. René Carraz and Yuko Harayama present Japan as a pivotal middle power state in global AI diplomacy, strategically navigating between the EU's rights-based and the US market-oriented approaches. They argue that Japan's leadership integrates voluntary soft law guidelines with binding international standards. Freddy Trinh, Alessandro Paccagnella, and David Burigana examine the high-stakes US-China contest for advanced semiconductors and AI, illustrating how these precursor technologies have become the primary terrain for geopolitical rivalry. Nils Koebis and Priya S. Nayar present the University Alliance Ruhr (UA Ruhr) as a leading model for how regional academic consortia drive science diplomacy through symmetric partnerships and transatlantic collaboration in high-stakes fields like AI and data science. Francisco Del Canto Viterale establishes that space diplomacy has transitioned from a relatively simple bipolar tool of the Cold War into an instrument essential for navigating a new space age defined by commercialization, militarization, and the rise of non-state actors like SpaceX. He posits that space diplomacy, the application of science diplomacy to the final frontier, serves as a critical conduit for reducing geopolitical tensions. Jean-Christophe Mauduit, Alexandra Klein, and Itteggbeyogene Ezekiel examine the Biological Weapons Convention (BWC) as a critical, yet strained, arena of science diplomacy. They argue that while the BWC established a global norm against biological warfare, it currently lacks the institutional support and robustness to keep pace with rapid advancements in synthetic biology, genome editing, and AI. Sumie Nakaya examines disaster resilience technology as a cornerstone of Japan's science diplomacy in the Asia-Pacific, the world's most disaster-prone region. She assesses Japan's non-intrusive, technical approach—leveraging remote sensing, AI, and big data as a confidence-building tool among regional neighbors. Taken together, the perspectives in this volume undergird polycentric science diplomacy as an ecosystem of arenas of action: sectoral regimes (e.g. chips, AI, space), organizational innovations (e.g. tech envoys, hubs, city labs), intermediary communities and actors (professional societies, women's networks), and transnational partnerships (e.g. transatlantic, Asia-Pacific, IGOs). The cumulative message establishes that the diplomatic task is less about restoring a singular center than about governing the interfaces among these centers to enable cooperation without collapsing into naïve and idealized openness or coercive and restrictive closure.

7 IMPLICATIONS: POWER, INEQUALITY, AND SOVEREIGNTY

Across this handbook, three broader implications emerge which together motivate a possible policy agenda. Power is increasingly exercised through terms of access, via funding conditions, standards and compliance pathways, and the platforms and supply chains that shape interoperability and dependency (Büthe and Mattli 2011; Farrell and Newman 2019; Zúñiga et al. 2024). Inequality is embedded in infrastructure and reflected in gaps in compute, data, standards participation, and the capacity to evaluate and audit systems. Strategic outcomes are shaped not only by a mismatch in funding or training but also by underlying material capabilities. The owners of these capabilities—whether state or non-state actors—function as key drivers, more strictly bounded by specific national or corporate interests. Sovereignty is thus an unbundled capability problem (Lüdert 2008). In a polycentric environment, strategic outcomes are dictated by the material capabilities of both state and corporate owners, sovereignty is no longer a given—it is an unbundled background condition of specific national and private interests. Sovereignty requires actors to have a choice over given technological paths, an ability to verify critical systems transparently, and the flexibility to exit proprietary ecosystems via open standards and credible substitutes (Ostrom 2010; Farrell and Newman 2019).

Building on these implications, we are able to distill possible policy priorities and design implications for polycentric SD. In particular, we advance a practical reorientation. SD should be treated not only as discourse or a kind of talk shop, but as a mechanism for lasting institutional and infrastructural design. The chapters collectively suggest five design principles that can help make polycentric science diplomacy both effective and publicly legitimate.

First, actors seeking resilient cooperation, including research funders, IOs, and research-performing organizations, should protect and *invest in epistemic commons*. The contributions demonstrate that such investment protects domains of cooperation specifically designed to withstand political shocks. It requires creating and maintaining spaces for shared inquiry, verification, and learning that are insulated, as far as possible, from immediate strategic bargaining. In other words, scientific freedom is not just a value—it is a requirement. Epistemic commons can include joint monitoring arrangements, shared scientific infrastructures, trusted channels for exchange, and collaborative frameworks that preserve the possibility of working with evidence even when diplomatic relations deteriorate. The purpose is not naïve openness, but resilience, ensuring that some cooperative capacity remains available when crises and uncertainty demand it most.

Second, authors underscore the need for *anticipatory governance* (Guston 2013). Especially in fast-moving technology areas, regulatory and diplomatic cycles are slower than innovation cycles, and furthermore complicated by the fact that uncertainty is not a temporary bug but a persistent and inherent background feature. Governments, IO secretariats, and major funders should shift from reactive rulemaking to foresight-led governance through horizon

scanning, scenario planning, and structured reflection on second- and third-order effects. This is, in practice, must be supported by establishing hybrid expert bodies and agile advisory arrangements that can operate credibly under conditions of uncertainty, connect technical with anticipated—even if unforeseeable—societal dimensions, and update guidance and legislation as insights into benefits and risks evolve (Guston and Sarewitz 2002; Stilgoe et al. 2013). Anticipation is therefore inextricably linked to a legitimacy strategy; it signals that institutions are not merely catching up to crises but actively steer trajectories responsibly and with agility.

Third, if authority is exercised through platforms, consortia, and standards bodies, those arrangements should be made *accountable by design*. As authority shifts into multi-stakeholder arrangements in these governance spaces, there is a risk that polycentricity becomes governance by proxy, power exercised through standards, funding, and access without clear mandates or public oversight (Abbott and Snidal 2009; Bütte and Mattli 2011). The policy implication is to embed transparency about decision rights and influence, robust conflict-of-interest safeguards, and meaningful inclusion in how these platforms are constituted and run. Accountability here is not just procedural; it also involves clarity about whose problems are prioritized, whose expertise counts, and how disputes are handled when interests diverge.

Fourth, the contributions point toward technological agency as well as an ability to situate geopolitical know-how as *core diplomatic capabilities* (European Commission 2025). If diplomacy increasingly depends on digital tools and technical infrastructures within a multipolar world, then uneven capacity to understand, procure, audit, and govern these tools becomes a potential source of dependency and exclusion (Farrell and Newman 2019; Jansen et al. 2023). Scientists and policymakers need to invest in institutional capabilities, especially for less-resourced states and organizations, to evaluate technologies, manage cybersecurity and integrity risks, negotiate procurement and partnership terms, and retain exit options. Done well, DiploTech can widen participation and effectiveness; done poorly, it can deepen asymmetric dependence and entrench the influence of actors who control platforms, data, and compute (Bjola 2022).

Finally, we find that it is important to reframe *open science as diplomatic design* rather than an aspiration that long hobbled SD as an idealized understanding of soft power. Openness is not a single policy choice; it is an intentionally built and safeguarded ecosystem of infrastructures, protocols, and institutional capacities that determine who can meaningfully participate and benefit (Star and Ruhleder 1996; Plantin et al. 2018). The implication is to build interoperability through open and harmonized standards where feasible, invest in shared evaluation and auditing capacity, and address practical barriers such as multilingual access and uneven digital infrastructure where possible. At the same time, openness must be aligned with research security, data governance, and fair benefit-sharing requirements that together strengthen resilience and legitimacy rather than becoming a channel through which inequality is reproduced.

Taken together, these principles, we trust, treat polycentricity neither as a problem to be eliminated nor as a virtue to be celebrated. It describes a set of design commitments aimed at governing interfaces, so that distributed authority and plural expertise can generate SD cooperation that is resilient, ethically grounded, and robust to the pressures of an age of disruption.

8 LIMITATIONS AND AVENUES FOR FUTURE RESEARCH

The scope of this handbook also reveals gaps that merit further work. While contributors bring perspectives from multiple regions, authors and cases centered on the Global South remain, despite concerted efforts by the editors, underrepresented. Future research in the next step flowing from this volume should engage Global South perspectives further, including South–South cooperation and the ways financing and infrastructure shape participation and influence, including in emerging governance platforms such as BRICS+ (Ruffini and Büyüktanır Karacan 2023; Rüland et al. 2023).

These limitations also reflect the way the handbook was assembled. The project began with an open call for contributions in 2023 and was subsequently shaped by discussions at the FUTURE FORUM: “Science Diplomacy in Era of Technological Disruption” 2024 in Washington, D.C., which was convened under the auspices of the German Center for Research and Innovation New York with the intent to foster global dialogue at the intersection of science, diplomacy, and technology. The forum’s focus on how AI, biotechnology, and other advances are reshaping international relations helped consolidate key problem framings and case-based insights, but it also inevitably mirrored where attention, resources, and organized expertise were most concentrated at the time. We are aware of these imbalances and intend to expand the handbook in a future edition, while also inviting additional authors, networks, and communities of practice to step forward with complementary chapters and case studies that broaden regional coverage and deepen perspectives from underrepresented regions.

A second limitation is thematic concentration. Several chapters focus on AI and its governance. That emphasis reflects both the prominence of AI in contemporary debates and the distribution of available proposals and practitioner networks that responded to the call and convenings. Future work should extend the analysis to other disruptive technologies and infrastructures, including quantum technologies, emerging biotechnologies, digital public infrastructures, and climate-related interventions, and examine how science diplomacy can shape their trajectories before path dependencies solidify.

9 LOOKING AHEAD

Science diplomacy in an age of disruption is about steering change under conditions of contestation and competition, where science and technology are no longer treated primarily as shared problem-solving resources but also as

strategic assets, sources of leverage, and targets of control. In such a setting, the work ahead is not simply keeping cooperation alive, but shaping the conditions under which it remains credible and useful: deciding what must stay open, what must be protected, and what must be rebuilt when trust erodes. Openness continues to generate immense benefits, speed, creativity, innovation, verification, and the capacity to respond to crises, but it also creates exposure to dependency, asymmetric benefit capture, politicized influence, and vulnerabilities in data, infrastructure, and supply chains. Treating openness as a design variable rather than a default stance is therefore central to contemporary science diplomacy.

For similar reasons, cooperation should not be confused as the opposite of security. In many domains, especially those with blurred dual-use civilian–military boundaries, the question is how to cooperate while managing risk in ways that are risk-reflexive, proportionate, and legitimate. Resilience here is not achieved by closing systems, but by building robustness into relationships and infrastructures. This may entail diversifying channels of engagement, maintaining spaces for verification and shared inquiry, and ensuring there are credible options to pause, contest, or exit arrangements that become coercive or politically untenable. The aim is not to insulate science from politics, an impossible and undesirable goal, but to prevent political contestation from collapsing the epistemic conditions that make cooperation functional and meaningful.

At the same time, the legitimacy of science diplomacy hinges on who is included and empowered to shape agendas, standards, and outcomes. Capability without legitimacy becomes brittle. It triggers backlash, erodes trust in expertise, and narrows the social mandate for cooperation inherent in scientific exchange. Expanding participation is therefore not only a normative objective but a practical one, because broad-based legitimacy makes agreements and collaborations more durable under pressure. Inclusion also has an infrastructural dimension because meaningful participation requires access to data, platforms, standards processes, evaluation tools, and spaces where expertise can be exercised without deference to dominant SD actors and centers.

We want to be clear that polycentric SD does not offer a single template, and it should not, because polycentricity describes a reality in which authority, expertise, and infrastructure are distributed across multiple, partially overlapping centers that vary by sector, region, and problem area. What works for disaster resilience may not work for AI governance; what stabilizes space cooperation may not translate to biotechnology; what is feasible in a highly resourced innovation system such as oncology research may not be feasible elsewhere. The value of the polycentric lens is that it helps actors see the field as it is: *crowded*, *contested*, and *fast-moving*, with power expressed through standards, funding, platforms, and access as much as through formal and informal negotiations. It also reveals where constructive action remains possible in designing institutions and partnerships that manage trade-offs openly, by building interoperability and exit capacity to reduce coercive dependence, and protecting epistemic commons that keep verification and learning alive even when geopolitics hardens.

Seen this way, the opportunities ahead are real but conditional. They lie less in restoring a singular multilateral center than in cultivating a resilient ecosystem of cooperation, multiple pathways, conveners, and arenas where public value can be pursued without collapsing into either naïve openness or coercive closure. The ambition is an accountable polycentric science diplomacy order. One that is able to absorb shocks, distribute agency more fairly, and keep science diplomacy ethically grounded as it navigates the contested politics of technological change that defines our presence and future.

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The Case for Science Diplomacy 2.0 in this Age of Technological Disruption

Krishna Ravi Srinivas 

1 SCIENCE DIPLOMACY: CRISIS AND CHALLENGES

Many chapters in this volume have come up with many suggestions for science diplomacy in theory and practice, ranging from a new heuristic (Tim Flink), chips diplomacy (Freddy Trinh), to cadre of technology envoys as diplomats (George Salter). This is not surprising as technological disruption and its implication for science diplomacy is taken into account by these authors. Similar views have been expressed elsewhere too, on the importance of science diplomacy as well as the need to revisit and revise the idea and praxis of science diplomacy. For example, while Turekian and Gluckman have underscored the importance of formal and informal science diplomacy and suggested that it should evolve to meet the emerging challenges (Turekian and Gluckman 2024), Zhang points out, “However, a hegemonic paradox in science diplomacy is that while it purports to have leveling effects and to cultivate mutual appreciation between advantaged and less advantaged societies, in practice it often re-affirms and perpetuates power imbalances” (Zhang 2022, 19). It has been suggested that science diplomacy should include and reflect voices and views from indigenous communities (Goveas and Sinha 2024).

The evolving global scenario is more complex with wars in Ukraine and the Middle East, the rise of techno-nationalism, changing dynamics between geopolitics and technology, particularly emerging technologies (Szczepeński 2024), and an increase in intensity of scientific research between the United States and China despite geopolitical tensions and sanctions by the United States against entities based in China (Li et al. 2024). Decoupling in trade and

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commerce is a reality, so is the rise of promotion of technological sovereignty and techno-nationalism. But it has been argued that technology sovereignty should not be equated with techno nationalism and collaborative technology sovereignty is possible (Lee et al. 2024).

The gap among countries in terms of R&D spending or capacity in science and technology (S&T) has not narrowed and while Europe, the United States, and China vie with each other for the top slot, R&D spending in many countries is less than 1% of their respective GDPs. In case of Sustainable Development Goals, the global record is mixed, but overall performance is far from satisfactory, and many goals are not likely to be achieved by 2030. If at all anything, the wars in the last two years have posed serious challenges to assumptions about international S&T cooperation and science diplomacy (Olšáková and Robinson 2022a). The return of Donald Trump as the President of the USA and the growing rift between the two major powers in science has muddied the milieu further. While the federal support for science in the USA may not decline, priorities may be different with less importance given to international cooperation and funding for UN agencies like WHO.

The renewal of the S&T agreement between the USA and China indicates that despite conflicts and growing distrust both countries see the need to cooperate and collaborate. Similarly, despite the war, science and scientists in Ukraine received support from many sources. But as Doubravka Olšáková and Sam Robinson point out, “It is time to stop mythologising Science Diplomacy as being an all-powerful tool and to admit its limitations. Now is also the time to question definitions of Science Diplomacy. Might not a new concept of science diplomacy emerge to serve the insecure world in which we live with its powerful nuclear armed dictators, its punishing injustices, its global challenges, and its continuing colonial legacies and mindsets?” (Olšáková and Robinson 2022b). They call for a return to a realist science diplomacy. Are we at the beginning of “a new era of ‘post naïve’ science diplomacy” as hypothesized by them? It is too early to tell. But irrespective of this conflict some scholars including Tim Flink have questioned the naïve assumptions and romanticization of science diplomacy (Rungius and Flink 2020). It is not that the supporters of science diplomacy are unaware of the impacts of the developments and the articles in the flagship journal *Science and Diplomacy*, and in *Issues in Science and Technology*, indicate that they are cautiously optimistic and still consider science diplomacy as an effective tool (“Science Diplomacy in a Fractured World.” 2025).

Some of the recent debates and discussions on Science Diplomacy while cautioning us also point out new ways to approach Science Diplomacy. For example, Ruffini and Arditti point out that science diplomacy aimed at addressing common interests and science diplomacy primarily serving national interests are two sides of the same coin (Ruffini and Arditti 2025). On the other hand e Shok takes a position that Science Diplomacy is evolving into a “twenty-first century work-in-progress” and points out that Science Diplomacy spreads through many channels including social media, informal channels and popular science outlets (Shok 2025). Calling for a trinodal model of Science Diplomacy, Turekian and

Gluckman call this as aspirational, pragmatic, and transactional approach. According to them, “Aspirational diplomacy builds empathy and long-term trust. Pragmatic diplomacy reinforces institutions and solves shared problems. Transactional diplomacy delivers immediate, nationally aligned outcomes” (Turekian and Gluckman 2025). Writing in another context Takemi et al. (2025) argue that Japan effectively used Science Diplomacy in facilitating diversity and inclusivity in the Hiroshima AI process and thereby thwarted fragmentation and promoted international AI governance (Takemi et al. 2025). According to Lubert, “Science diplomacy therefore must grapple with challenges imposed by non-scientific power political considerations. A ‘new’ science diplomacy may contribute to civil society dialogue, to a sustainable development of society and economy, as well as to acknowledging national interests” (Lüdert 2024).

These indicate that there is a rethink on Science Diplomacy in theory and practice. Obviously in these times taking a cautious optimist stand is a pragmatic one.

I think irrespective of the cautious optimism it is time to rethink science diplomacy as it is traditionally understood and practiced. More importantly it is also time to think beyond the state and state-led or sponsored processes and institutions as the core components in science diplomacy. But science diplomacy is not an innocent or activity based solely in altruism. As Ndzendze and Marwala (2021, 144) point out, “For the transferring states, on the other hand, science diplomacy allows them to supplement its foreign policy credentials. Increasingly, science and technology diplomacy are major concepts in many countries’ soft-power arsenals.” In the recent years concepts like city-led science diplomacy and science paradiplomacy have been espoused (Roig et al. 2020; Piaget and De Lombaerde 2024).

Having stated that I am cautious to state that they are in initial stages and their usefulness and relevance is not yet known categorically. Although theoretically they sound relevant and novel, how practical are they is a big question. Cities and subnational governments may have the potential to engage in science diplomacy and science paradiplomacy, respectively, but their impact can be limited on account of constraints like lack of capacity, constitutional constraints that limit the scope for their collaboration, or their authority to practice paradiplomacy. An important constraint is while cities are hubs for innovation and are globally well connected, they cannot act as mini republics, nor the subnational governments may have the authority to engage in science diplomacy. They can supplement and complement national science diplomacy policies and strategies but cannot emerge as an alternative or substitute. But when science diplomacy is conceptualized differently and is inclusive in theory and practice, they have a positive role to play as active stakeholders. Imagine a state like California or a city like Bengaluru (Bangalore) engaging in science diplomacy with all the intellectual and technical prowess they have. They can make a huge difference and may become partners in mega-science projects.

We need alternative histories of science diplomacy as these will help us to think beyond the traditional narrative on science diplomacy. Kunkel (2021)

cautions against “easy sounding solution” and points out that science diplomacy has not been an easy or smooth process and has had tensions, difficulties, and failures. But if we go back in time and trace the history of science diplomacy, there are interesting insights and narratives. According to one such narrative “The concept of scientific diplomacy in the Anglo-Saxon cultural space has a complex and multifaceted trajectory, which can be traced from its origins in the seventeenth century to its contemporary application. Throughout this trajectory, various geopolitical interests, philosophical utopias, and power dynamics have played a significant role” (Islas Morales et al. 2024, 29). It can be argued that the history of science diplomacy can be a contested one that goes beyond narratives focusing on state led initiatives, giving voices to others who have been active in one way or other, but not recognized (see, for example, Robinson et al. 2023).

2 TOWARD SCIENCE DIPLOMACY 2.0

The idea of science diplomacy 2.0 is not new, nor is there a consensus on what exactly it is and how different it is from science diplomacy. At best it is a new idea yet to be translated into practice, at worst it is a vague concept, yet to be developed and tested.

The Madrid Declaration on Science Diplomacy (2019) states that science diplomacy is a tool for developing bilateral and multilateral relationships and its definitions and applications have been broadened significantly in the recent times, and links that with the increasing understanding of the role of science and technology in meeting challenges of the societies. The Declaration concedes that definitions of science diplomacy have been broadened but that broadening works within the traditional understanding of the role and need for science diplomacy. Similarly, a New Protocol for Science Diplomacy has been proposed (S4D4C n.d.). Taking a very different position, Siddhartha argues, “Given those origins and some current modes of use of the expression ‘science diplomacy’, post-colonial states should perhaps question its appositeness to the purposes of their diplomacy. Indeed, those South states which have grown significant autonomous scientific and technological capabilities—and have developed them also to militarily usable ends—might consider eschewing the expression altogether, if only to pre-empt a neo-colonial attitude subliminally diffusing into their diplomats when practicing the art of ‘science diplomacy’ with co-South states” (Siddhartha 2019, 1). But in my view, this is not likely to happen as developing countries seem to be emulating the North more in traditional science diplomacy than showing interest in developing a new lexicon or new concept of science diplomacy.

On the other hand Turchetti and Lalli (2020) have proposed a science diplomacy 2.0 which is data based and adopts “trans-disciplinary and integrative research” underscored by innovation observatories and based on responsible innovation. Such a conceptualization is novel, and the objective is a relevant one. However, given the issues in global governance of data such an

ambition may not fructify unless countries are convinced that such a science diplomacy and observatories are in their interest. While their “co-productionist” approach is relevant, there are serious limitations in realizing that in practice, given the divide between scientists and others including laypersons and indigenous communities. More importantly, this science diplomacy 2.0 adds new layers to science diplomacy and enriches it. The current frameworks in science diplomacy which are largely state and science institutions centric may not be agile enough to put that to practice. Standard science diplomacy discourse is state centric and relies on institutions like national science academies and science and foreign ministries to promote and nurture it. But there is more to global and national science than them and there are other stakeholders. The current discourse neither acknowledges that nor takes them into account.

There have been many non-state actors that have been active in matters of science diplomacy, global development, and international affairs (Marton et al. 2024). Similarly, there are various civil society groups that work on various themes, ranging from science communication to climate change. It is true that they are fragmented, often at odds with states, and are not part of traditional science academies or global science networks formed by scientists and professional scientific bodies. As indicated earlier, cities can be potential agents in science diplomacy. In case of climate change, there are alliances of cities and these alliances and networks.

An elephant in the room is the hi-tech industry that today is in the forefront of science and innovation. Google or Microsoft, or similar big companies, invest heavily in both basic and applied research. This is true of many companies in the Global South, particularly in China. Of course, this is not new, as there have been examples before such as GE and Bell Labs. But the reach and impact of the big tech firms today is more global than ever. The big tech is also active in shaping regulation of emerging technologies and endeavors to deploy hi-tech for common good through different initiatives. For example, Google has programs in India that are tailored to meet needs of the Indian society in sectors such as health and education. Such companies constitute what Turekian and Gluckman call Technopoles (Turekian and Gluckman 2024).

I hypothesize that science diplomacy 2.0 will have to take these into account. Science diplomacy 2.0 thus cannot be defined by the three categories espoused by the American Association for the Advancement of Science (AAAS) and the Royal Society in their 2010 document that has formed the basis for most of the discussions on science diplomacy in the last two decades. It is also pertinent to know that over the last few decades, different categories of diplomacy ranging from health diplomacy to digital diplomacy have been theorized and practiced. Science diplomacy today has to not only consider these but has to learn from them, particularly in the post COVID and climate change challenged world. So, science diplomacy 2.0 will have to consider that these diplomacies are also necessary to address global challenges, and it has to work with them. For example, health diplomacy’s importance goes beyond the post-COVID scenario as new challenges including future pandemics cannot be wished away. The

inability of nations to agree to a Pandemic Treaty also underscores the point that despite good intentions and potential, health diplomacy also faces big challenges. Similarly, disinformation and misinformation on a global scale, threats like deep fakes, pose a major challenge to digital diplomacy. On the positive side, how digital diplomacy can advance the objectives of the Global Digital Compact is an important issue.

Science diplomacy 2.0 will include but go beyond track 2 diplomacy. It will need new alliances and coalitions with participation from stakeholders who have not been part of traditional science diplomacy. There will be contradictions in any such alliance for obvious reasons. In traditional science diplomacy, the actors share a common understanding and vision, and work in tandem as in the case of nation states and the respective national academies of sciences, or with intergovernmental organizations where states are the constituent members. Hence, among the three categories, including science in diplomacy and science for diplomacy, there is an inherent coherence.

But in science diplomacy 2.0 this is not likely to happen. The alliances and coalitions while working toward a common agenda will have to deal with internal contradictions also. New organizations similar to Pugwash (Kraft 2022) may arise to intervene in global affairs relating to the governance of emerging science and technologies. It is also likely that UN institutions will be involved more in science diplomacy 2.0 as the UN is getting engaged with science and technology more directly through mechanisms and newly created institutions such as the UN Office for Digital and Emerging Technologies, while now it is UNESCO that is more active in science diplomacy.

The major question is who will spearhead science diplomacy 2.0 and whether it will take shape in the near future and be an agent of change. I do not want to speculate on this but believe that time is ripe for science diplomacy 2.0 to take shape although it may be called so. Rather, we may see traditional actors in science diplomacy joining hands with stakeholders who are part of science diplomacy 2.0 to launch new initiatives or institutional mechanisms in matters relating to emerging technologies. These initiatives and mechanisms may be the initial spaces that can open up more opportunities and fora to those stakeholders. For example, the Global Digital Compact initiated by the UN in 2024 and endorsed by all member states recognizes the role of the private sector and seeks to broaden the work on realizing the objectives of the Compact, particularly in addressing the digital divide. Similarly, the UN resolution on Capacity Building in AI can be a good starting point for using science diplomacy 2.0 (United Nations 2024a).

3 SCIENCE DIPLOMACY 2.0 AND GOVERNANCE OF ARTIFICIAL INTELLIGENCE

In the literature there has been discussion on harnessing artificial intelligence (AI) for diplomacy or for that matter diplomacy. There can be no dispute regarding the use of AI for science diplomacy. But a more important question

is how science diplomacy can contribute to governing AI, particularly globally. The global governance of AI is fragmented and while nations are chartering their own ways to govern AI, there is a sort of consensus on guiding principles and ethics such as UNESCO's AI Ethics. Similarly, there is greater awareness and concern on risks emanating from the deployment of AI as evident in a series of international conferences on AI and risk. On the other hand, as the technology is fast evolving and getting deployed, there are formidable challenges in governing AI, particularly at the global level. In fact, there is no consensus on whether the world needs an international agency to regulate AI. The panel appointed by the UN in its final report strangely makes no mention of science diplomacy, which is a puzzle (HLAB-AI 2024; United Nations 2024b).

Science diplomacy 2.0 is better suited to deal with AI than the current science diplomacy, as it will be inclusive and more participatory. It will give ample scope for the innovating big tech firms as well as groups that are working to democratize AI and other technologies. Obviously, there will be contradictions, differences in agendas and expectations, and points of disagreement. At the same time there will be scope to build consensus on some aspects such as good practices, realizing responsible AI in practice, and adopting a commonly agreed code of ethics. In fact, science diplomacy 2.0 can give a big push to soft law for governing AI as it can bring together stakeholders to build a consensus on using soft law. But given the complexities in global governance of AI, science diplomacy 2.0 can play a role that needs extensive multi-stakeholder engagement, track 2 diplomacy, and building a minimum level of consensus that can result in better outcomes and build trust among stakeholders and reduce the gaps in communication and understanding among them. Ideally speaking, the UN Office for Digital and Emerging Technologies can take the initiative to adopt science diplomacy 2.0 to bring together the stakeholders on achieving the objectives of the Global Digital Compact and taking forward the UN resolution on Capacity Building in AI (United Nations, 2024c). As pointed out earlier in this Chapter Japan has used Science Diplomacy successfully ensuring acceptability and participation in the Hiroshima AI process. Similarly Switzerland is using its status as a neutral broker to harness Science Diplomacy for facilitating collaboration and co-operation among diverse stakeholders to use AI for humanitarian and other purposes in the larger interest (Mesot, 2025).

There is an emerging literature on AI and Diplomacy and how AI is used in diplomacy (e.g. Mostafaei et al. 2025, Kilburg 2026). But we need more work in terms of theory and practice on using Science Diplomacy for AI governance and related objectives and how AI can facilitate better conceptualization and use of Science Diplomacy. This will be all the more relevant in case of Science Diplomacy 2.0.

All said and done, these are exciting and challenging times for science diplomacy and all the more for science diplomacy 2.0. This brief article has touched upon some aspects of this, highlighting the need for science diplomacy 2.0. If there is no Science Diplomacy 2.0, it is the right time to invent it and translate that as praxis.

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Geopolitics and Science Diplomacy

J. Duberry and L. Langlois

1 INTRODUCTION

Science and technology have long been entangled with international power relations. From nuclear physics and space exploration to digital infrastructures and artificial intelligence (AI), scientific knowledge has shaped military capabilities, economic competitiveness, and diplomatic influence. Yet science is no longer only a strategic resource to be mobilised by states; it has become a site of geopolitical contestation in its own right. What is increasingly at stake is not simply access to technologies or research outputs, but control over the rules, infrastructures, and authorities that determine how knowledge is produced, validated, circulated, and rendered usable for governance. Export controls, research security frameworks, funding regimes, and visa policies actively structure epistemic communities and condition the production of authoritative knowledge. Moreover, science and scientific integrity are increasingly contested and politicised, with both results and research processes being questioned in different political contexts, including Brexit, the COVID-19 pandemic, and crackdowns on academic freedom in Turkey and Hungary.

Traditionally treated as a largely internal matter of scientific self-regulation—anchored in norms of integrity, peer review, openness, and academic

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J. Lüder, M. Wählisch (eds.), *The Palgrave Handbook of Science Diplomacy*,
https://doi.org/10.1007/978-3-032-29473-9_3

freedom—epistemic governance is now increasingly shaped by security logics, geopolitical rivalries, and strategic competition. The concept of epistemic governance has emerged from diverse strands of scholarship to capture a shift in governance from the allocation of resources and organisational control toward shaping how knowledge is produced, selected, and used in society (Jacob and Hellström 2018). It highlights how power in policymaking is exercised through the production, circulation, and institutionalisation of knowledge claims that define what is considered true, credible, and appropriate, thereby guiding action by acting upon shared epistemic premises (Alasuutari and Qadir 2014). This perspective is particularly relevant for analysing contemporary science–policy relations, as it directs attention to how scientific expertise, evidence, and integrity become central instruments through which power and authority are enacted in global governance.

This chapter argues that these dynamics signal the emergence of epistemic governance as a central object of geopolitical struggle. It challenges three dominant assumptions. First, it questions the view that science diplomacy is primarily about facilitating cooperation and dialogue under conditions of political tension, arguing instead that it is increasingly concerned with governing epistemic legitimacy. Second, it challenges the assumption that scientific integrity, trust, and advisory authority can be treated as stable, internal norms insulated from geopolitics. Third, it problematises the tendency to frame research security and technological competition as exceptional disruptions to an otherwise neutral global science system.

These assumptions are no longer adequate in a context where geopolitical rivalry targets scientific institutions, infrastructures, and fundamental principles. As geopolitical competition intensifies and global inequalities deepen, scientific integrity, trust, and accountability are no longer stable background conditions of international cooperation. Instead, they have become contested political objects—subject to negotiation, securitisation, and strategic manipulation. This chapter advances a central claim: in a fragmented and multipolar world order, science diplomacy is increasingly about maintaining scientific integrity and trust under conditions of geopolitical contestation. Understanding science diplomacy today therefore requires moving beyond cooperation-centric frameworks and confronting the politics of epistemic governance that now sit at the heart of science–policy relations.

The chapter develops this argument in two sections. It first examines why epistemic governance has become contested, showing how states actively govern knowledge flows and leverage research collaboration, funding, and regulation as instruments of power across cases from China, the United States, and the European Union. It then turns to what is at stake when epistemic governance is destabilised, focusing on how challenges to scientific integrity, trust, and advisory systems—particularly in domains such as artificial intelligence and emerging technologies, redefine the purpose and practice of science diplomacy.

From Scientific Capacity to Epistemic Governance

Science and technology have long been embedded in international power relations. The rise of the nation-state, the colonial enterprise, and the consolidation of empire were accompanied by the patronage of selected sciences and the exploitation of local knowledges and techniques from the “periphery” for the benefit of the “metropolis” (MacLeod 2000). World War II did not merely consolidate the links between science and the state to achieve specific practical objectives; it irreversibly embedded science at the heart of political processes, as the war demonstrated the immense contribution of science-based technologies—such as the atomic bomb, radar, guided missiles, and new drugs like penicillin—to national defence and health (Kevles 1995).

Diplomacy, understood as the institutionalised system through which states manage complex and continuous relations (Berridge 2003), has evolved alongside successive waves of technological innovations that compressed distance, accelerated communication, and transformed how diplomatic relations are exercised across borders. More recently, digital technologies have expanded the realm of diplomacy, opening up new spaces (such as social media platforms, cloud infrastructures, and data centres), incorporating new actors (including technology companies, data brokers, and hackers), and introducing new tools ranging from spyware to data analytics.

Emerging technologies such as quantum computing, biotechnology, and artificial intelligence (AI) both furnish diplomats with new tools and raise novel governance challenges, while also reconfiguring the balance of power. These technologies have broad military and civilian applications, making them defining features of contemporary world affairs. In the case of AI, recent scholarship shows that it does not merely facilitate diplomatic interaction—such as digital peace dialogues—but actively reshapes the epistemic and institutional conditions under which diplomacy and governance unfold, altering how knowledge, authority, and legitimacy are produced (Wählich and Kufus 2025). The pursuit of technology leadership has fuelled geopolitical tensions as recently illustrated by emerging “chip wars” (Miller 2022), and attempts to safeguard their sovereignty and enhance technological autonomy. As diplomats engage in increasingly technical debates and negotiations concerning emerging technologies and their societal and geopolitical implications, they must operate at the intersection of technology, ethics, and geopolitics (Liebetrau and Monsees 2024).

Originally coined by Johan Rudolf Kjellén in 1899, the term “geopolitics” emerged within imperialist discourse (Ó Tuathail and Toal 1996) at a time where the territory of Sweden was in between two large powers, Russia and Germany. In its most classical definition, it conceptualises the relationship between politics and geography (Flint 2021). Today, geopolitics is gaining prominence in an international context characterised by growing polarisation, fragmentation, and multipolarity. It is invoked across a wide range of contexts—from European Union policy discourse (Haroche 2023) to art (Ingram

2016), film festivals (de Valck 2007) and sport (Stanfill and Valdivia 2017)—reflecting a broader shift in how the international order is imagined. Whereas the 1990s and early 2000s were dominated by narratives of globalisation and the “global village,” contemporary geopolitical discourse increasingly emphasises contestation, rivalry, and fragmentation. But geopolitics is not only a catchphrase for great power rivalries understood in a broadly realist sense (Nickel 2024). It describes also specific lenses to analyse and understand international affairs through power and competition.

Science and Technology are at the heart of states’ competition to identify sources of competitive advantage, such as enhanced military capacity, innovation, developing human capital, and strengthening a country’s reputation (Cantwell and Grimm 2018). Control over frontier technologies—whether in AI, biotechnology, space, or advanced manufacturing—functions as a mechanism of power, reinforcing asymmetric interdependence between states. Access is selectively granted according to alliance structures and security considerations, while restrictions are increasingly justified in the language of national security and economic competitiveness. As Matthews (2006) demonstrates, scientific and technological capability gaps are actively governed through geopolitical strategies that regulate cross-border flows of knowledge, talent, and infrastructure. Yet the geopolitical significance of science cannot be reduced to competition over technological capabilities or innovation outputs alone. What is increasingly contested are the rules, infrastructures, and authorities through which knowledge itself is produced, circulated, and recognised as legitimate.

This chapter conceptualises these dynamics through the lens of epistemic governance. Most accounts conceptualise epistemic governance as the direct or indirect effects of governance arrangements on knowledge production and use, whether enacted intentionally by identifiable actors or unintentionally through second-order effects of policy instruments such as funding mechanisms and evaluation systems (Jacob and Hellström 2018). Some approaches adopt a more explicitly normative stance, most notably Pearce and Raman (2014) and Raman (2014) argue that the production and selection of knowledge for policy require a distinct layer of governance, particularly in relation to contested domains such as risk, health, and the environment. Other perspectives emphasise the discursive and material dimensions of epistemic governance. Drawing on governmentality and policy learning, Alasuutari and Qadir (2014, 2016) conceptualise epistemic governance as operating through discourse, shaping how actors perceive reality, responsibility, and appropriate action on the basis of perceived epistemic and moral authority rather than coercion. Complementing this view, Normand (2016) and Kauppi (2018) highlight the role of metrics, statistical technologies, and representational tools in structuring the conditions under which knowledge gains credibility.

Although states remain central actors in the geopolitics of science, epistemic governance is not exercised by states alone. It is enacted through a dense and heterogeneous constellation of actors, including international organisations, funding agencies, standards bodies, expert panels, and universities themselves.

International organisations and technical bodies shape epistemic authority by setting norms, coordinating expertise, and legitimising particular forms of knowledge in global governance. Funding agencies structure research agendas and epistemic priorities through allocation mechanisms and evaluation criteria. Standards bodies embed technical choices into infrastructures that stabilise specific knowledge claims over time. Universities, meanwhile, increasingly function as quasi-diplomatic actors, navigating geopolitical risk, negotiating access to funding and collaboration, and mediating between scientific autonomy and political accountability. Epistemic governance thus emerges from the interaction of these actors across multiple levels and jurisdictions, rather than from state control alone.

It is also important to distinguish epistemic governance from the narrower notion of knowledge or research security. Epistemic governance refers to the ways in which actors seek to shape others' conceptions of reality, including what counts as valid knowledge, credible evidence, legitimate expertise, and appropriate action (Alasuutari and Qadir 2014). While securitisation is one prominent mode through which epistemic governance is currently enacted, it does not exhaust the concept. Epistemic governance also includes productive and constitutive forms of governance, such as agenda-setting, standardisation, legitimacy-building, and the organisation of advisory authority. These practices determine not only what knowledge must be protected, but what knowledge is prioritised, trusted, and mobilised for policy. Framing contemporary dynamics solely through the lens of research security risks obscuring how power operates "positively"—through funding priorities, institutional design, expert selection, and norm-setting—rather than only through restriction and control.

The following sections examine how these dynamics are institutionalised in distinct ways across the United States, China, and the European Union. Each case highlights a different modality of epistemic governance—national security, technology autonomy, and conditional funding and openness—illustrating how geopolitical rivalry is affecting the institutions, regulatory regimes, material infrastructures, and normative frameworks that shape how scientific knowledge is generated, validated, shared, and translated into policy-relevant expertise. As this chapter shows, these dynamics are not novel to today's fragmented and multipolar international order; they have, however, accelerated markedly and demand renewed attention at a moment when the legitimacy of both multilateral diplomacy and scientific integrity is increasingly contested, often in favour of bilateral arrangements and the instrumentalisation of science.

The United States: Security and the Governance of Knowledge

From the early Cold War onwards, debates over scientific openness and national security have repeatedly surfaced at the intersection of research, diplomacy, and geopolitics in the United States. These debates reveal a persistent tension between the strategic value of scientific exchange and concerns that openness could enable adversaries to acquire sensitive knowledge.

Federal support for science expanded dramatically in the first decade of the Cold War, from approximately \$75 million in 1940 to \$1.5 billion by 1945, declined slightly by 1950, and then increased sharply to \$3 billion by 1953, doubling again by the late 1950s, with the vast majority of funding—around 90 percent in 1950—directed towards defence-related research through the Department of Defense and the Atomic Energy Commission (Krige and Barth 2006). In this context, scientific agendas, organisational arrangements, and norms of expertise became increasingly tied to national security priorities.

At the same time, leading scientists publicly defended international scientific cooperation as both scientifically and politically desirable. During well-known US Senate hearings in 1949, J. Robert Oppenheimer argued in favour of exporting radioisotopes for basic research (Oppenheimer 1949), framing openness as a cornerstone of responsible scientific leadership. A few years later, Edward Shils reacted strongly against McCarthy-era restrictions on visas for foreign nationals (Shils 1952). These concerns resurfaced with particular intensity during the late Cold War. In response to accusations that US universities were leaking militarily relevant knowledge to communist states, the Panel on Scientific Communication and National Security concluded in 1982 that open scientific communication posed little immediate military risk when compared to other channels of technology transfer. While acknowledging espionage concerns, the panel emphasised that the benefits of international scientific exchange outweighed the potential near-term security costs. A similar position was reaffirmed in 1999, when the Committee on Balancing Scientific Openness and National Security argued that sustained international engagement was indispensable if the United States was to maintain technological leadership, even at the risk of some illicit information loss.

Yet, national security actors increasingly articulated a counter-narrative. In 1982, Deputy Secretary of Defense Frank Carlucci warned that the Soviet Union was systematically exploiting scientific exchanges as part of a centrally coordinated effort to enhance its military capabilities (Carlucci 1982). These concerns prompted a major policy response, culminating in National Security Decision Directive 189 (NSDD 189) in 1985. While acknowledging that US universities and laboratories were targets of foreign intelligence, NSDD 189 reaffirmed that scientific creativity depends on an open research environment. It defined “fundamental research” as research whose results are ordinarily published and shared broadly, and stipulated that such research should remain unrestricted to the maximum extent possible, with classification—rather than informal controls—as the primary mechanism for addressing genuine security risks (The White House 1985).

However, this settlement proved fragile: by focusing narrowly on research outputs, the Fundamental Research Exclusion neglected the processes of knowledge production and circulation, leaving room for expanding surveillance and regulation (Krige 2014). From the late 1990s onward, export control regimes were progressively extended to encompass not only physical artefacts but also knowledge itself. Under the “deemed export” rules,

information or technology does not need to cross national borders to be treated as an export; disclosure to a foreign national within the United States is legally considered an export to that individual's country of origin. Preventing a deemed export is the primary compliance issue facing university research (University at Buffalo [n.d.](#)).

Taken together, these developments illustrate how security-driven concerns have been institutionalised into a broader regime of epistemic governance in the United States. Export controls, compliance requirements, and research security frameworks do not simply protect sensitive technologies; they actively reshape the conditions under which scientific knowledge can be produced, shared, and recognised as legitimate. By governing mobility, collaboration, and advisory authority, these mechanisms redefine the boundaries of acceptable scientific practice and expertise. Scientific openness thus persists not as a universal norm, but as a conditional privilege mediated through security assessments and institutional oversight.

At the same time, epistemic governance increasingly intersects with domestic political dynamics, as the authority of universities and science is itself contested as a source of legitimate policy knowledge. Scientific expertise and evidence are often portrayed by political actors as elite, partisan, or politically charged, particularly in media environments shaped by opinion-driven narratives and strategic storytelling. As a result, science as a foundation for policy legitimacy is challenged, and in some contexts displaced, by knowledge claims aligned with political identities and interests, placing epistemic governance at the centre not only of geopolitical rivalry and national security, but also of domestic political agendas. This phenomenon relates to what Nichols (2017), writing in the context of contemporary debates in the United States, describes as the “death of expertise”: “a Google-fueled, Wikipedia-based, blog-sodden collapse of any division between professionals and laypeople, teachers and students, knowers and wonderers” (p. 61). This dynamic is also visible in debates around emerging technologies such as AI, where expert authority is often placed on the same level as the opinions of non-experts in public and political arenas (Duberry and Hamidi 2021; Duberry 2022).

China: State-Led Science and Strategic Knowledge Governance

Over the past seven decades, China's scientific and technological development has evolved from a strategy of catching up with advanced economies to one increasingly oriented toward technological autonomy and leadership. This shift was articulated early on in the *Science and Technology Development Plan (1963–1972)*, which established for the first time the principle that the modernisation of science and technology constitutes a foundational condition for the modernisation of agriculture, industry, and national defence.¹ From the

¹ Party Literature Research Centre of the CPC Central Committee (2011). Cited in Hu et al. (2024).

outset, science was thus positioned not as an auxiliary domain, but as a central pillar of national power and state-building.

This trajectory reflects a distinctive development model driven by innovation and enabled by the interaction of technology acquisition, imitation, and indigenous innovation, amplified both by the scale of China's domestic market and by sustained engagement with global scientific systems (Hu et al. 2024). China's reform-era strategy deliberately combined openness to global science with strong national steering, allowing Chinese institutions to internalise global epistemic norms—such as publication, benchmarking, and peer review—while maintaining political oversight over strategic direction and priorities (Marginson 2021). Internationalisation was thus conceived not as dependence, but as an accelerator of domestic capacity-building.

Institutionally, this approach has been consolidated through China's system of Five-Year Plans, which since the adoption of the First Five-Year Plan in 1953 have served as central policy instruments through which the Communist Party of China articulates national priorities for economic, social, and scientific development. These Plans function not only as resource-allocation mechanisms, but also as instruments of epistemic governance, structuring research agendas, institutional hierarchies, and strategic sectors. The *14th Five-Year Plan*, adopted in March 2021, provides a comprehensive blueprint for the period 2021–2025, reaffirming priorities such as digitalisation, innovation-led growth, and green development, while explicitly adapting them to intensifying domestic constraints and geopolitical tensions (Kwong 2025).

In this context, scientific and technological self-sufficiency has become a central objective of China's most recent planning cycles. This emphasis reflects the spillover of geopolitical competition—particularly with the United States—into the domain of science and innovation (Mallapaty 2021). AI occupies a particularly prominent position within this strategy. Chinese policymakers have consistently framed AI as a general-purpose technology and a cornerstone of China's ambition to become a global technology superpower (Luong and Fedasiuk 2022). As comparative analyses of dual-use AI governance show, China's institutional configuration—characterised by close alignment between civilian research, industry, and state priorities—reduces the barriers between scientific research and strategic application, reinforcing perceptions of AI as a geopolitical rather than purely economic domain (Carrozza et al. 2022).

China's geopolitical approach to science is also evident in its external scientific relations. As Suttmeier's historical analysis of Sino-US science and technology cooperation demonstrates, scientific collaboration has long functioned as an instrument of diplomacy, strategic alignment, and capacity transfer, particularly during the Cold War and post-Cold War periods (Suttmeier 2010). While initially asymmetrical, this cooperation played a critical role in rebuilding China's research and higher education systems and embedding them within global knowledge networks.

Taken together, these developments illustrate a form of epistemic governance in which the Chinese state actively aligns knowledge production,

institutional authority, and international engagement with long-term geopolitical objectives of technological autonomy and leadership.

*The European Union: Openness, Soft Power,
and Conditional Cooperation*

Since formally identifying science diplomacy as a policy instrument in 2012, the European Union has used scientific cooperation to strengthen relations with key countries and regions, particularly by addressing shared global challenges such as health and climate change. Through successive Framework Programmes—ranging from Framework Programmes and Horizon 2020 to Horizon Europe—the EU has promoted principles of “Open Science” and “Open to the World,” fostering international collaboration, researcher mobility, and shared access to research infrastructures as central elements of its external engagement strategy. These programmes do not merely finance research; they organise transnational epistemic communities, allocate prestige, and structure research agendas through thematic priorities, evaluation criteria, and governance rules.

The EU progressively moved from a liberal agenda centred on openness toward a more selective and protectionist stance, driven by heightened geopolitical tensions, security concerns, and perceived threats to its economic position and normative values (Bamberger and Huang 2025). As a result, participation in European research programmes has become a powerful lever in the EU’s external relations. The case of Switzerland illustrates this clearly. In June 2021, the European Commission decided to exclude Switzerland from full participation in Horizon Europe following Switzerland’s withdrawal from negotiations on a comprehensive institutional framework agreement. Research programme access thus became explicitly entangled with broader political negotiations, with Horizon Europe functioning as a bargaining instrument in EU–Swiss relations (Guglielmi 2022).

This was not without precedent. Switzerland’s earlier partial suspension from EU research funding in 2014 following its decision to limit immigration—resulted in a documented decline in the number of international research collaborations coordinated by Swiss universities. Levels of collaboration recovered only after Switzerland was fully reinstated in European research programmes in 2017, underscoring the extent to which EU funding structures shape access to networks, infrastructures, and the production of authoritative knowledge (Cavallaro and Lepori 2021).

Similar dynamics are visible in the EU’s relationship with the United Kingdom (UK). The exclusion of UK institutions from full participation in Horizon Europe following Brexit illustrates how research funding functions as a geopolitical tool under conditions of political uncertainty. Political risk associated with Brexit led to a sharp decline in international research collaborations involving UK firms even before formal withdrawal, highlighting the sensitivity of scientific cooperation to shifts in legal and political alignment (Osswald and

Pierk 2020). Although access to EU research funding was later partially restored as political negotiations progressed, the episode revealed how deeply European science is embedded in institutional and geopolitical frameworks.

Taken together, these cases illustrate a broader transformation in the EU's approach to science as soft power. Research funding, collaboration, and infrastructure access are no longer neutral facilitators of cooperation but instruments through which political alignment, trust, and legitimacy are negotiated. Scientific cooperation becomes conditional, and openness selective.

From the perspective of epistemic governance, this evolution is critical. By conditioning access to funding and networks on political alignment, the EU shapes not only who participates in scientific cooperation, but whose knowledge becomes visible, credible, and policy-relevant. Science diplomacy, in this context, shifts away from the facilitation of exchange towards the governance of trust, risk, and legitimacy, anticipating the challenges to scientific integrity and advisory systems explored in Part 2.

Over the course of history, modern science has developed into a collective endeavour meant to produce reliable and shareable knowledge yet likely to be challenged. A set of epistemic norms underpinned this purpose—methodological rigour, intellectual honesty, and publishing of results—and gradually established the social and political credibility of science. However, its foundations have nowadays become fragile with the growing automation of cognitive processes, the politicisation of expertise and the increasing strategic uses of knowledge.

The rapid integration of AI systems into the production and use of scientific knowledge is exacerbating these concerns. By reconfiguring decision-making chains, complicating technical mediation and opacifying certain stages of analysis, AI is operating a shift in the conventional sources of accountability and epistemic trust (Mittelstadt 2019). Concurrently, science is increasingly being leveraged as a resource in public policy and international negotiations, hence directly exposing its own norms to geopolitical and diplomatic engagements (Crawford 2021). In this respect, scientific integrity can no longer be understood solely as an ethical requirement specific to the scientific community; it has now become a structuring issue intersecting ethics, public trust, and global governance.

This section argues that scientific integrity must be understood as a fragile normative principle likely to be constantly negotiated and to be preserved closely based on institutional mechanisms, scientific advice, and science diplomacy, most especially in the age of artificial intelligence.

2 BRIEF ACCOUNT OF THE NORMATIVE GENESIS OF MODERN SCIENCE AND TRUST BUILDING

The emergence of modern science marks a historic break with forms of dogmatic authority and knowledge based on tradition or revelation. Great thinkers, such as René Descartes in his *Discourse on the Method*, promoted an

approach based on methodical doubt, observation, and rationality, with the purpose of correcting human biases and identifying verifiable foundations as the building blocks of knowledge. As Shapin (1996) showed, a transformation of this sort was not only epistemological, but also social and political, with the process involved redefining the conditions for knowledge legitimacy.

Beginning in the seventeenth century, science gradually became institutionalised as a collective endeavour, namely through the creation of scientific academies like the Royal Society and the Académie des sciences. The purpose of those institutions was to ensure that knowledge was publicly accessible, cumulative, and subject to criticism, thus contributing to the emergence of common norms governing the production of knowledge. This process was explicitly formalised during the twentieth century in the work of Merton (1973), who identified the normative principles of communalism, universalism, disinterestedness, and organised scepticism as the normative foundations of modern science.

These norms were instrumental in building trust in science, by implementing mechanisms to distinguish reliable knowledge from opinion or belief. However, trust was based on a largely implicit assumption: that scientific processes were essentially considered transparent, intelligible and under researchers' direct control, a condition historically related to conventional forms of reasoning, experimentation, and result validation (Shapin, 1996; Ziman, 2000).

However, this configuration is now being extensively challenged by the widespread use of computational mechanisms and artificial intelligence systems that automate certain cognitive operations and reconfigure the means of scientific knowledge production and validation. Based on the mass exploitation of databases and use of machine learning techniques, including deep learning based on neural networks—these systems introduce forms of opacity into the chains of reasoning and decision-making processes that underpin scientific activity. Moreover, AI development complicates the traceability of methods, the interpretability of results and the direct accountability of researchers, thereby shifting the conventional terms of accountability and epistemic trust on which the normative order of modern science was founded (Burrell 2016; Ganascia 2017, 2022).

Artificial Intelligence and Shift in Epistemic Trust

The growing integration of AI systems into scientific practices marks a new milestone in the history of human-knowledge mediation. AI allows the automation of certain cognitive operations—big data analysis, modelling, prediction—which were previously performed directly by researchers. While AI tools yield considerable gains in terms of efficiency and analytical capacity, they also raise fundamental issues regarding transparency, interpretability, and epistemic accountability (Floridi et al. 2018).

Unlike conventional scientific instruments, many algorithmic systems operate based on partially opaque logic; as a result, it becomes harder to identify biases, implicit assumptions or trade-offs built into algorithmic models (O'Neil,

2016). Opacity challenges the conventional terms of intellectual honesty that is historically linked to researchers' individual accountability. Hence, epistemic trust tends to shift from human expertise to complex socio-technical mechanisms involving logic sometimes beyond human interpretation.

In this respect, science is faced with growing tensions between, on the one hand, the requisite reliability and cumulativeness of knowledge and, on the other hand, the increasing complexity of chains of knowledge production. These issues are exacerbated by the intensive use of scientific expertise in public policy, since results from algorithmic systems can directly impact political and social decisions.

Scientific Integrity: Definition, Scope, and Limitations

Through such a transformation process, the concept of scientific integrity takes on its full meaning. The term "integrity," from the Latin *integritas*, defines what is whole, intact, and unaltered. Applied to science, this concept refers to the preservation of the internal consistency of knowledge production processes and compliance with the methodological and ethical principles that guarantee their reliability and shareability.

Scientific integrity is not limited to an individual virtue or a mere ethical requirement. As pointed out by Resnik (2011), it is a systemic property of scientific activity meant to maintain unity between methods, data, interpretations, and end purposes. Historically implicit in intellectual honesty and methodological rigour requirements, integrity has gradually become institutionalised with the growing complexity of science and is now at the core of public policy (Merton 1973; Ziman, 2000).

But it seems that scientific integrity, far from being a guarantee per se, has nowadays become a fragile, constantly negotiated condition. Its scope for producing and mobilising science depends closely on institutional mechanisms, governance frameworks, and relationships of power that are often subtle and hard for the unwary to perceive. In settings marked by strategic competition and the automation of cognitive processes, integrity tends to be challenged by the logic of optimisation, speed, and efficiency as well as by the logic of power likely to conflict with transparency and reflexivity requirements.

Integrity, Ethics of Accountability, and Trust

From this perspective, scientific integrity can be understood as the operational substantiation of the ethics of accountability applied to the production and use of knowledge. In line with Weber (2013, 2003) and Jonas (2024, 1990) and as applied to this ethical understanding, the scientific community is expected to assume not only the methodological validity of their work, but also the social, political, and institutional impact of the knowledge produced.

Integrity translates this requirement into tangible norms that ensure science is both reliable and publicly accountable: data transparency, clarification of

uncertainties, and prevention of conflicts of interest. Public accountability is the foundation of trust; it is understood not as blind adherence to scientific authority, but as a rapport conditional to the ability of institutions to demonstrate, over time, consistency between values, procedures, and outcomes.

As shown by Oreskes (2019), Bachmann and Zaheer (2013), and several recent studies, trust in science is rooted in the existence of robust mechanisms with a lesser focus on the absence of error. These mechanisms allow to identify limitations, correct biases, and account for methodological choices, besides rethinking the social and political terms of trust in science. In the age of artificial intelligence, such a requirement becomes central to maintaining the legitimacy of science in the public and political arenas (Dawson et al., 2024; Dawson and Lock 2025).

Despite existing control and transparency mechanisms, trust in science remains fragile. Methodological limitations, institutional biases, and external constraints can compromise scientific integrity and, as a result, require the assessment of integrity failings and their implications to ensure the credibility of science and its role in the public and diplomatic spheres.

The Failings of Integrity and Diplomatic Impact

The failings of scientific integrity go far beyond the individual conduct of researchers. The growing challenge to scientific advice, often compounded by polarising policies and the spread of misinformation, affects the means of science to contribute effectively to public policy (example: IPCC). When scientific processes are perceived as opaque or biased, public trust is eroded and the social acceptability of expertise-based decisions is undermined.

At the international level, such issues contribute to weakening the role of science in multilateral negotiations, particularly in sensitive areas like climate change, global health, and artificial intelligence. Science plays a key role in scientific analysis by providing common frameworks towards overcoming political divides. When the integrity of knowledge is called into question, science loses its mediating function, paving the way for challenging assessments and collective inaction. Earth-observation satellites, for instance, constitute a key infrastructure for climate data (Wang et al. 2025). Recent US budget decisions have included cuts to some of these programs (Webber 2025).

Integrity failings also erode trust between partners in international scientific cooperation. Tensions are particularly salient in North–South partnerships or certain strategic areas, where gaps in institutional capacity can heighten perceptions of unfairness or dependency (UNESCO 2017).

Science Diplomacy and Scientific Advice: How to Preserve Norms in the Age of AI to Address Failings

In the face of integrity failings, science diplomacy and scientific advisory mechanisms likely serve as central instruments for preserving and reaffirming norms

of integrity. By establishing sustainable spaces conducive to dialogue between science and public decision-making, they help to maintain shared norms of rigour, transparency, and independence, even in matters marked by polarisation and geopolitical competition.

The role of scientific advice is not limited to providing technical opinions; it also involves bringing to light the procedures, uncertainties, and trade-offs that structure the production of knowledge. Overall, integrity is addressed as a normative collective good through science diplomacy, by fostering coordination across states and mitigating the impact of power asymmetries.

As highlighted in the *Science Diplomacy in an Era of Disruption* report, strengthening such mechanisms is essential to protect the credibility of science and support international cooperation in a fragmented world order (AAAS and Royal Society 2025). In the age of artificial intelligence, the preservation of scientific integrity can no longer be separate from the governance and science diplomacy mechanisms bound to ensure its transparency, accountability, and legitimacy in the face of unprecedented global challenges.

This chapter has shown that science is no longer merely affected by geopolitics; it has become one of its central terrains. Across different political systems, states and regional actors do not only compete over technological capabilities or innovation outputs, but increasingly over the rules, infrastructures, and authorities that govern the production, circulation, and validation of knowledge. As a result, the central challenge for science diplomacy is no longer simply how to facilitate scientific cooperation under conditions of geopolitical tension, but how to sustain the conditions under which scientific knowledge remains governable, credible, and usable for collective decision-making.

Epistemic governance thus emerges as a critical site where power, inequality, and legitimacy intersect—where geopolitical competition increasingly targets not only what knowledge is produced, but how truth claims are authorised, how uncertainty and risk are managed, and how responsibility is distributed across human and technical actors. In AI-mediated contexts in particular, the opacity of decision-making processes and the fragmentation of accountability complicate traditional norms of scientific integrity, rendering trust less a matter of methodological soundness alone than of institutional transparency and reflexive governance.

While states have long sought to harness science for power and security, the argument advanced in this chapter is not that geopolitics has newly entered science, but that geopolitical contestation now increasingly targets the governance of epistemic authority itself. What is at stake are the institutions, rules, and infrastructures through which knowledge is rendered credible, legitimate, and actionable—under conditions where integrity can no longer be assumed as a stable guarantee, but must be actively maintained. This shift cannot be reduced to familiar dynamics of technological competition or securitisation alone, nor does it imply that epistemic governance is monopolised by states. On the contrary, it is exercised through dense constellations of actors—including funding agencies, universities, standards bodies, expert panels, and

international organisations—whose authority is shaped by historically unequal knowledge systems and enduring asymmetries of power.

Part 2 extended this analysis by examining what is at stake when epistemic governance is contested in practice. It showed how challenges to scientific integrity, trust, and advisory systems—particularly in domains such as artificial intelligence and other emerging technologies—reshape the relationship between science, policy, and diplomacy. When the rules and infrastructures underpinning knowledge production and validation become politicised, the integrity, trustworthiness, and accountability of scientific expertise can no longer be taken for granted. Rather than functioning as stable background conditions for international cooperation, they become objects of negotiation.

Ultimately, this chapter argues that the future of science diplomacy will depend less on the ability to promote cooperation per se than on the capacity to govern epistemic conditions under strain. What is at stake is not simply who innovates fastest or leads technologically, but who defines and upholds the norms through which knowledge claims can circulate, endure, and inform collective decision-making. In an increasingly fragmented and AI-mediated world order, preserving scientific integrity and public trust emerges not as a peripheral ethical concern, but as a central diplomatic and political challenge.

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Exit, Voice, and Loyalty: A Realistic Heuristic for Science Diplomacy

Tim Flink

1 SCIENCE DIPLOMACY: FROM GLOBAL EUPHORIA TOWARD REALISM

From the 1990s through the first decade of the twenty-first century, liberal democracies and transitioning states alike entered a period of remarkable expansion in international science, technology, and innovation (STI) as well as higher education (HE). Cross-border knowledge production flourished, universities grew in number and reach, and student mobility became a defining feature of academic life (Powell et al. 2019). These shifts were propelled by the global forces of technological change, particularly advances in information and communication technologies, alongside liberalized borders and intensified flows of capital and people (Appadurai 1996). As collaboration across national boundaries deepened, research consortia and funding organizations evolved into multi- and supranational structures (Nedeva 2013; Flink 2016). Universities and research-performing institutions extended their presence through international branch campuses and liaison offices, while large-scale research infrastructures emerged as truly global enterprises (Hallonsten 2016). In parallel, science diplomacy networks took shape or expanded—bringing together science attachés, counselors, and targeted funding programs designed to institutionalize scientific cooperation across borders (Flink and Schreiterer 2010).

Bibliometric analyses during this period revealed strong correlations between rising investments in international STI and higher education and the growing volume and impact of cross-border scientific publications (Wagner and

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Leydesdorff 2005; Wagner and Jonkers 2017). At the same time, science demonstrated its expanding societal reach, positioning itself as an essential force in addressing grand global challenges (Flink and Kaldewey 2018) and generating economic value through innovation and productivity (Stephan 2012). The globalization of universities and the mainstreaming of intercultural learning further consolidated a transnational model of higher education—one that standardized human resource formation, supplied market economies with talent (Wildavsky 2012; Drori et al. 2002), and deepened the structural ties between international STI collaboration and global economic competition (Brown and Tannock 2009).

While science and higher education could increasingly reconnect with their historical roots as a global system of knowledge production and validation—ideally unbound by particularistic interests (Daston 1991; Edmondson and Edelstein 2019)—foreign policy simultaneously discovered the appeal of science as a seemingly apolitical, cross-border resource of “soft power” (Nye Jr. 2008) to influence foreign governments and societies. In 2010, the Royal Society and the American Association for the Advancement of Science proposed an influential heuristic for science diplomacy (AAAS and Royal Society 2010), and scholars published the first internationally comparative study that articulated three logics of action for this emerging field (Flink and Schreiterer 2010). These early practical and analytical efforts (see also Ruffini 2017) were soon followed by a second wave of political and scholarly interest, including three large-scale collaborative EU research projects, which together helped consolidate science diplomacy as a concept and practice and attracted substantial attention from policy communities (as thoroughly documented by Ruffini 2020).

Two decades later, however, a new realism has tempered the earlier euphoria surrounding science diplomacy and international STI collaboration more broadly. Global challenges such as climate change, its adverse effects on living conditions, and pandemics like COVID-19 have indeed spurred open-minded collaborations among academic researchers and stakeholders from multiple sectors. Yet, these initiatives have been increasingly overshadowed by economic and security concerns voiced by nationalist actors, revealing how often key players prioritize self-interest even when they confront shared global problems (Molotoks et al. 2021; Schermerhorn et al. 2022).

At the same time, students, researchers, and research managers have found themselves exposed to humanitarian crises, political upheavals, wars, and purges initiated by authoritarian regimes against other states or their own citizens. In recent years, Scholars at Risk—a network of 500 universities across 38 countries—has supported a growing number of researchers seeking refuge (Adebayo 2022; Cole 2017). Dedicated funding schemes such as Germany’s Alexander von Humboldt Foundation’s Philipp Schwartz Initiative, the French PAUSE program, and the Institute of International Education’s Scholar Rescue Fund have become oversubscribed. This troubling development is echoed by the Academic Freedom Index (2026), which documents a

deterioration in conditions for academics worldwide in the context of rising authoritarianism.

Escalating geopolitical tensions have also reshaped the landscape of STI and higher education more directly. Espionage, disinformation campaigns, and cyber-attacks targeting knowledge infrastructures and governments have become routine challenges for science diplomacy actors and domestic policy-makers alike. These practices exploit the vulnerabilities of a system historically organized around openness and shared knowledge (Conrad 2021). Often described as “hybrid” threats, they blur boundaries between state agencies—frequently in authoritarian regimes—and private or semi-private entities. Against this backdrop, debates on research security have flourished. Once mainly associated with technical issues such as laboratory safety, research security now primarily refers to protection against international threats and has become a central topic at conferences and workshops, as well as a focus of new international and national policies and institutional measures. These efforts aim to raise awareness, analyze cross-border risks, and shield research institutions from disinformation, intellectual property theft, and other forms of destructive interference (for many, see Fulda 2024; Shih 2024).

The interconnected architecture of cyberspace has dramatically amplified the reach of espionage and cyberattacks targeting public and private STI institutions. These threats have grown in scope and sophistication, largely because science and higher education occupy pivotal roles in developing and applying key technologies—the foundations of contemporary industrial and security policy (Aiginger and Rodrik 2020). Their cross-sectoral utility makes them essential engines of economic growth, strategic competitiveness, and innovation across industries. Currently, forty-four such technologies are identified as central to global security and market leadership, grouped into eight major domains: advanced materials; photonics and optical technologies; quantum technologies; digital and information technologies; chemical technologies; nanotechnologies; life sciences and biotechnology; and engineering and fabrication technologies (European Parliament 2021; Schmidt 2023). Crucially, many of these technologies possess dual-use potential—simultaneously serving civilian and military or repressive purposes—blurring ethical boundaries and complicating international cooperation. Consequently, STI collaborations with authoritarian regimes, which often exploit both the transformative potential of these technologies and the structural vulnerabilities of open societies, have become increasingly problematic (Tiffert 2020; Walker 2022).

In summary, several critical trends now define the global STI landscape: (1) an expanding number of STI actors are situated within, or directly linked to, authoritarian regimes; (2) STI drives the development of key technologies, while higher education supplies the requisite human capital; (3) these technologies carry inherent dual-use potential; and (4) freedom of inquiry in science, technology, and higher education—particularly within the social sciences and humanities—is under tangible threat.

The convergence of these dynamics has deeply politicized the international sphere of STI, posing acute challenges for science diplomacy actors (Flink and Stüwe 2023). First, the normative tenets of science—communalism, universalism, disinterestedness, and organized skepticism (Merton 1973)—are increasingly difficult to uphold when governments and private actors restrict free inquiry or instrumentalize scientific openness for geopolitical or economic gain. Second, the international dimensions of research integrity have become politically weaponized. Issues once resolved within epistemic communities now risk being publicly exploited in the service of national agendas. Third, international STI collaborations face intensified scrutiny and, at times, moral condemnation: researchers who share knowledge or work too closely with actors from authoritarian systems may be accused of enabling technological outcomes that undermine liberal norms and security.

As a result, science diplomacy practitioners now navigate an environment of unprecedented normative and strategic complexity. Translating foundational principles into coherent daily practice has become increasingly fraught. Existing heuristics—whether those distinguishing the means and ends of science diplomacy (AAAS and Royal Society 2010, 2025), that is, “diplomacy for science,” “science in diplomacy,” and “science for diplomacy,” or “access,” “promotion,” and “influence” (Flink and Schreiterer 2010)—offer valuable conceptual scaffolds but nowadays fall short of addressing the new geopolitical realities. Because existing heuristics model unidirectional actions, while neglecting the interactive and reciprocal nature of science diplomacy, in which actors must continually respond to foreign or scientific initiatives, manage domestic coordination, and weigh the unintended consequences of their engagement (Ruffini 2020).

This chapter, therefore, advances a realistic and explicitly pragmatic heuristic to guide decision-making in this transformed environment. While it neither operationalizes full-fledged sociological theory nor prescribes a particular research program, its purpose is to help science diplomacy actors assess actions, anticipate responses, and prepare for potentially deleterious developments in an era defined by geopolitical tension. Acknowledging that STI and higher education have recently turned inward to interrogate their own normative responsibilities within society, we argue that these norms acquire practical meaning only when practitioners recognize their conditional applicability under current geopolitical pressures—especially amid the resurgence of global authoritarianism and a new class of tech oligarchs.

This new global environment demands a heuristic that moves beyond the optimism and linearity of earlier science diplomacy frameworks. This heuristic adopts a realistic lens, grounded in the recognition that international science and technology interactions are inherently shaped by power, competition, and normative asymmetries. It does not seek to replace the afore-mentioned typologies, but rather to complement them by clarifying how actors can anticipate, interact, respond, and adapt under geopolitical constraints.

2 BRIDGING NORMATIVE PRINCIPLES WITH ECONOMIC THINKING

Science diplomacy stands at the crossroads of two normative systems—those of international politics and of global science. From diplomacy, it inherits the principle of reciprocity, the idea that favors, benefits, or sanctions extended by one state to another are returned in kind (Constantinou et al. 2016). In the absence of a global hegemon, mutual expectations of order are maintained through formal institutions—treaties, agreements, embassies—and through professional structures populated by diplomats, ministerial staff, and liaison officers (Keohane 1986; Meyer et al. 1997). These frameworks set the stage for predictable interaction: nation-states may collaborate, compete, or—at their worst—clash, but ideally within an institutionalized order.

Science, for its part, rests on its own moral compact. Its actors believe to be governed by norms of communalism, universalism, disinterestedness, and organized skepticism (Merton 1973). Ideally, knowledge production transcends borders, unencumbered by national or political interests (Schott 1993). When deviations occur, the community itself defines and enforces standards, framing lapses as matters of research integrity (Kleinert and Anderson 2013).

Science diplomacy, by definition, draws upon—and often fuses—these two normative logics (critically discussed by Rungius and Flink 2020). Yet even as a growing strand of discourse calls for more ethically balanced or “fair” collaboration (Sinha 2023; Polejack et al. 2022), it rarely confronts an uncomfortable truth: that competition among science, technology, and innovation (STI) actors is now inseparable from national economic competition (Ruffini 2020; Flink 2020). The global STI arena is a hybrid ecosystem of scientists, technologists, entrepreneurs, and government agencies—most still organized along national lines—who simultaneously collaborate and compete across borders. Reciprocity, in this context, serves not only moral ideals but also pragmatic economic interests. Even under strained international relations, science diplomacy practitioners have traditionally invoked four recurring arguments to justify continued scientific engagement:

- Historical precedents: Referring to stable collaboration even during geopolitical rivalry (e.g., Soviet–Western exchanges during the Cold War; see Kraft 2022).
- Depoliticization: Framing scientific cooperation as detached from politics and devoted solely to the production of knowledge (Flink and Kaldewey 2018).
- Bridge-building: Highlighting science as a conduit of understanding between divided societies (Lord and Turekian 2007).
- Continuity: Arguing that maintaining contacts may help sustain relationships through periods of authoritarian rule and prepare for future change (von Feigenblatt 2019; Schweitzer 2004).

Today, however, such arguments appear increasingly fragile. We are witnessing the rise of authoritarian modernity (Thompson 2019): a form of governance that blends market-friendly economics with centralized political control. Authoritarian-capitalist regimes—most visibly China and unfortunately, an eventuality in current developments within the United States—have adopted institutions associated with open markets, achieving impressive GDP growth, technological prowess, and global competitiveness. They present their model as more efficient than liberal democracy, claiming to deliver prosperity without pluralism. The phenomenon is not confined to a few major powers. Democracy indexes consistently record a 16-year global decline in liberal governance. Roughly two-thirds of governments now enjoy domestic support for authoritarian practices, as long as these regimes deliver economic gains and raise living standards beyond thresholds once thought to guarantee democratic consolidation. This global trend erodes the normative attraction of liberal democracy (Mounk and Foa 2018) and, with it, undermines reciprocity as a reliable organizing principle—whether in collaboration or competition.

Within this reality, the assumption that scientists can remain detached from societal and political responsibilities appears increasingly untenable. The intertwining of global STI networks with key technologies—many of them dual-use—makes contact with authoritarian systems all but inevitable. Such interactions carry risks of moral compromise, strategic exploitation, or complicity by omission (Flink et al. 2025). If science diplomacy aspires to remain credible and effective, it must grapple with these new conditions. Maintaining free, secure, and socially responsible international collaboration requires acknowledging—once and probably for all—that science does not operate in a neutral or insulated environment, despite its actors' self-characterization.

A realist and economic mindset becomes indispensable. Science diplomacy can no longer rely solely on traditional moral appeals or institutional trust; it must engage with the logic of incentive structures, interdependence, and strategic calculus. The challenge, then, is twofold: How can actors protect the openness essential to scientific progress while recognizing the geopolitical asymmetries that shape the arena in which they operate? And how can reciprocity—once grounded in mutual benefit—be reinterpreted under conditions where economic pragmatism often trumps shared norms?

Boiling these essential questions down to the individual level of decision-making, science diplomacy actors must be prepared to answer two concrete questions, a purely economic and a normative one:

1. How should one actor respond when another is likely to defect in a sequence of interdependent actions?
2. Can any chosen response ensure a result no worse than the status quo ante—for all parties involved, including unintended third ones?

Grappling with these questions reveals the deepening complexity of global politics and underscores the need for a more nuanced understanding of

international scientific exchange in an age of resurgent authoritarianism. To analyze behavioral patterns, actions, and reactions in such contexts, science diplomacy practitioners might turn to Albert O. Hirschman's seminal work *Exit, Voice, and Loyalty* (1970). Although first conceived to explain responses to decline within firms and institutions, Hirschman's heuristic applies across scales—individual, organizational, and state—and offers a powerful lens for managing relationships under strain. His framework identifies three archetypal responses when actors experience deterioration or harmful behavior from their counterparts:

- Exit: Withdrawing from an unsatisfactory arrangement—such as a customer switching to a rival supplier or a partner terminating collaboration.
- Voice: Expressing dissatisfaction to provoke change—through protest, negotiation, or calls for reform.
- Loyalty: Remaining committed despite discontent, based on faith in eventual improvement or a sense of shared purpose.

These responses are fluid and interdependent. The possibility of exit can strengthen voice by adding leverage; loyalty can delay exit and create room for persuasion; and voice may serve as a constructive alternative when leaving would foreclose future cooperation. Far from offering a simple binary between departure and endurance, Hirschman's heuristic highlights the communicative space in which actors—scientific or political—seek to recalibrate relationships rather than abandon them outright.

While the model shares affinities with behavioral game theory and collective action frameworks (Clark et al. 2013), its accessibility lies in its pragmatic orientation: it helps actors confront real-world deterioration rather than assume ideal cooperation. The following sections apply Hirschman's logic to illustrative decision-making scenarios in science diplomacy. Each scenario begins with a short narrative case, followed by a decision matrix and a discussion of potential consequences, providing both analytical clarity and practical guidance (Table 4.1).

Example 1 Let us imagine that two states (S1 and S2) have established STI collaborations for three decades. However, in the course of time S2 is—or has turned—autocratic, pressuring its researchers and students to exploit foreign knowledge resources by any means necessary. Some researchers of S2 might resist their government's directives; others comply with its demands for various reasons. As a consequence, STI actors in S2 have ceased sharing their findings, while researchers from S1 face surveillance and aggressive recruitment efforts by institutions S2. Meanwhile, bi-national research collaborations between S1 and S2 are becoming increasingly tedious, the properties of their governance can be characterized as more top-down. Negotiations with respect to new bilateral joint funding programs, data sharing, and intellectual property rights

Table 4.1 Potential actions and consequences for STI actors of S1 in response to developments in S2

	<i>Exit</i>	<i>Voice</i>	<i>Loyalty</i>
Government	Phase out bilateral STI funding with S2; embargoes against institutions and/or individual researchers of S2 are being executed. Existing collaborations are intensely surveilled	S1 science attachés and ministerial staff from foreign and STI ministries submit complaints to S2 ministries and STI actors	Government actors of other policy fields in S1 will need to compensate for exit and voice strategies chosen in the field of STI policy, e.g., asserting that economic or cultural relations would not be affected
Funding agencies	Transaction costs for S1 agencies and potential negative consequences by their own government cross out further binational funding programs. Funding agencies do not respond to calls for joint meetings anymore, as regards bilateral funding programs. HE mobility programs get cancelled	S1 agencies file complaints against S2 agencies and set an ultimatum to change funding conditions of S2 and collaborative STI practices of their researchers	Funding agencies can keep up bi- and multilateral funding programs in areas that are not prone to hot STEM topics. Collaborations as regards joint grand challenges (climate change, pandemic prevention) might be continued
Research performing institutions	Universities and research institutes risk losing their credibility if upholding exchange with their counterparts of S2. In exceptional cases, they may maintain partnerships with universities that they know continue to provide safe spaces for critical, independent academic research, if only clandestinely	University presidents complain to their colleagues abroad and urge them to sensitize their researchers to act in a collaborative manner. They also pledge that S2 university heads should extend concerns to their governments	Stating that individual researchers enjoy freedom of expression, S1 universities sensitize their staff about risks when collaborating with S2 STI actors, but do not intervene
Individual researcher(s)	Some S1 researchers stop engaging in further project collaborations, as they realize that they have been short-changed	Informally, S1 and S2 researchers can evaluate the current geopolitical situation affecting their relation; S1 researchers propose that S2 influence their government to change course	Researchers keep collaborating, partly due to a lack of awareness or in full awareness of potential problems

from joint research projects have become difficult. If we further imagine that STI actors of S2 get perpetually caught committing data theft on the soil of S1's research institutions, how would different actors in the category of government, public research funding, research-performing institutions, and individual researchers interpret such a situation and respond?

Potential Consequences 1 The consequences of S1's response to S2's actions can vary significantly across different institutional levels. While stopping bilateral STI collaborations with S2 or embargoing its researchers and institutions (exit), S1 diplomatic actors can lodge formal complaints against S2 (voice) while simultaneously urging its own domestic STI actors (in particular researchers and STI performing institutions) to remain vigilant regarding breaches of research integrity and potential STI espionage activities. S2 has several options:

- (a) Change its own policy radically in order to restore trust and general diplomatic cooperation with S1, thereby accepting criticism and require its STI actors to alter their behavior.
- (b) Maintain its aggressive stance and observe if S1 will implement stronger measures at governmental or sub-governmental levels (potentially leading to mutual exit).

It is important to note that if S1's government opts for an exit strategy, it must do so in domestic coordination with its own STI performing and funding actors. In some states, the constitutionally guaranteed freedom of scientific research may render governmental exit strategies against other states and their STI and HE institutions ineffective, if diplomatic communications lack domestic support. To put it bluntly, inasmuch as science diplomacy actors might choose exit or voice options, their own STI performing actors might keep collaborating in full awareness of the deleterious behavior of their counterparts. Therefore, exit responses must be carefully considered and orchestrated at home, taking into account dependencies and alternative options. Simultaneously, actions that are clearly detrimental to one actor cannot be met with loyalty. The chosen example currently reflects the problematic situation that the United States and European states face when dealing with several states worldwide, most notably China. The level of STI interdependence between Western states and China is high, in particular economically. As we can see, Western state governments act carefully in exiting their bilateral STI engagement. While Western states do not kowtow but clearly address issues of espionage and unfairness in collaborations, some governmental partnerships are exited, while STI actors are not necessarily prohibited from collaborating individually with their international counterparts. At the same time, governments urge their own STI actors to invest into their research security and awareness respectively, to question dubious partnerships, and to start tightening their export control measures in regard to technologies of potential dual use (Table 4.2).

Table 4.2 Potential actions for S3 in response to developments in S4

	<i>Exit</i>	<i>Voice</i>	<i>Loyalty</i>
Government	S3 actors aim at retaliating and intend to leave other fields of STI collaborations too. Science attachés might stay in the country observing the technological development of S4 actors	S3 science diplomats initiate a dialogue on the civil and peaceful use of a new key technology with dual-use application potential. Before the intense IPR negotiations, stakeholders are pushing for an economically fair solution that benefits both sides	Acknowledging that circumstances may change, S3 continues to regard science policy as a marginal cultural issue and maintains a mildly diplomatic approach toward S4, as long as trade relations and security issues remain unproblematic
Funding agencies	S3 funding agencies follow suit to their government's policy and either alter IP conditions in bilateral funding agreements or leave joint programs	Remind partner institution of a joint legacy of co-development and threaten to terminate joint research programs	Understand political shift in priorities and seek for alternative joint funding topics; offer possibilities of reuptake
Universities	S3 university administrations instruct researchers to withhold, as far as possible, technologically relevant and commercially exploitable knowledge from collaborations with S4 partners	Remind partner institution of a joint legacy of co-development and threaten to terminate joint research programs	Keep relations in good faith while switching topics of research, teaching, and knowledge transfer; headhunting activities will increase
Individual researcher(s)	Seek stop collaborations and seek for alternative partners	Researchers can act annoyed and complain about shifting terms of collaborations	Researchers keep good contacts knowing that competition is politically induced while alternative topics and ways of collaborating are still a viable option (conference visits, discussing theory-building, etc.)

Example 2 Two states, S3 and S4, have enjoyed a long-standing and trusted relationship in STI collaborations. These collaborations have been smooth, with STI actors from both systems sharing common ground. Recently, the development of a new key technology by these actors has reached a phase nearing market readiness. Although both governments constitutionally guarantee research freedom, S4 has begun to adopt competitive and exclusionary practices against S3. This shift has led S4 to terminate binational funding schemes for specific scientific programs and discourage its domestic STI actors from engaging in further collaborations with S3.

Potential Consequences 2 This example demonstrates that diplomatic responses to shifting strategic and economic priorities rarely warrant abrupt exit strategies. In a context where alternative actions are feasible, and maintaining relations for STI actors remains a reasonable option (albeit in different ways and topics), exit and retaliation strategies are often counterproductive. Research-performing entities are likely to intensify efforts to recruit talented researchers from the competing side. Individual researchers may consider exiting collaborations, but only if viable alternative partners are available. In most cases, the optimal approach is to maintain existing contacts while adapting to the new circumstances. In any case, partnerships get increasingly evaluated with respect to the market potential of STI developments. For governmental actors, however, it remains hard to assess the “readiness” of technological development, particularly in areas where the distinction between basic and applied research gets blurred, such as in the material or life sciences. In case of obvious rogue behavior, voice is often the most feasible option to choose from. It can lead back to fair behavior or—in the case of deteriorating responses—can still be followed by exit strategies.

Example 3 S5, a highly industrialized state, and S6, a developing state, have established numerous collaborations in HE and research. However, S6 turned autocratic, implementing measures that severely restrict academic freedom and autonomy. These measures include suppressing the freedom of expression, nationalizing STI and HE competencies, implementing surveillance of universities, students, researchers as well as classroom and academic content. The autocratic regime in S6 has taken harsh actions against dissenting academics and intellectuals: It intimidates and represses deviant intelligentsia including measures of guilt by association, it imprisons critical thinkers, while there are even reports of torture against some academics. As a result, many critical academic researchers, artists, intellectuals, and journalists are fleeing S6, seeking refuge abroad. This situation presents a significant challenge for the existing collaborations between S5 and S6, raising ethical concerns about continued engagement in light of human rights violations and academic suppression (Table 4.3).

Potential Consequences 3 This example reflects the current responses of governments and STI actors in the EU following Russia’s attempted invasion of Ukraine, but it can be expanded to other incidents, such as the Arab Spring and other autocratic states that brutally suppress attempts of civil society’s organized protests. In the case of the war Russia started against Ukraine, official binational funding schemes were immediately frozen, and formal letters of complaint were sent while awaiting responses from Russian universities in February and March 2022. After a joint letter from university presidents and prominent researchers praised the Russian government regarding its actions in Ukraine, formal collaboration agreements were terminated. Despite this, informal contacts between researchers

Table 4.3 Potential actions for S5 in response to developments in S6

	<i>Exit</i>	<i>Voice</i>	<i>Loyalty</i>
Government	S5 stops all project funding and formal collaborations as best as possible	S5 science diplomats submit a complaint to S6 ministries and STI actors	Possibilities of letting academic researchers and students leave their countries are established. Intelligence will vigilantly screen candidates that seek refuge abroad
Funding agencies	Agencies do not engage in binational funding agencies anymore. Liaison offices get shut down, some might offer stipends to academic asylum seekers	S5 agencies file complaints against S6 agencies and urge their counterparts to exert influence, if possible, on the governing regime to stop its atrocious purges	Funding agencies keep up bi- and multilateral funding programs
Universities	Universities step out of research collaboration agreements with state-driven counterparts	University utters a note of protest while offering individual track-2 possibilities of communication	Universities know about the complexity and multifaceted realities in their once partnering institutions, they try not to shut down all levels of exchange
Individual researcher(s)	Reluctantly, researchers stop projects with state-aligned researchers	Researchers unship invitations to colleagues from S6 to attend conferences, sit on boards or review academic works	Researchers keep up informal contacts with trusted colleagues, fully aware that this could put their colleagues in a dangerous situation

have been maintained, and funding agencies have been providing opportunities for Russian academic researchers and students to leave the country. Few liaison offices for research funding organizations have remained operational, partly in the hope that the situation may change swiftly or that options for trusted local staff could be offered either to leave the country or to gradually phase out their work contracts. In terms of diplomatic language, governments and STI actors have emphasized that relations are not terminated but merely “frozen” for the time being, leaving open the possibility of reinstating collaborations in more favorable political circumstances (see Flink and Stüwe 2023).

While this example might appear clear-cut as regards unequivocal exit communication vis-à-vis an authoritarian aggressor, it needs to be assessed closer. First, because the Russian government did not command war against in February only in 2022, but already in February of 2014 by invasion of the Crimean Peninsula. And second, because plenty of documented cases exemplify Russia’s hybrid warfare, also targeted against universities and innovation-oriented entities in Central and Eastern just as well as Western Europe. This had not prompted science diplomats to exit from collaborations and calls for

reprocessing actors' strategies in STI. Science diplomacy actors must learn to set boundaries for their international partners much earlier when faced with latent dangers, threats, and brutalization. At the same time, they must more critically examine statements from their own STI actors who, even in the wake of Russia's invasion attempt in Ukraine, regretted having to give up certain collaborations. For example, claims that there would be no alternatives to do climate research on permafrost soils or to build up physical infrastructures turned out to be overdrawn.

3 HIRSCHMAN'S MORAL IMPLICATIONS FOR SCIENCE DIPLOMACY

In times of strategic uncertainty, reviving Hirschman's "Exit, Voice, and Loyalty" offers science diplomacy practitioners not a realistic moral compass but a practical one—a tool to navigate deteriorating relations and assess the ripple effects of their own and others' actions. Its appeal lies precisely in what it does not demand: the impossible task of judging moral intention. Instead, it rests on an interest-oriented foundation that integrates ethical foresight with pragmatic realism (Rescher 2002). Fairness, in this view, emerges not from moral speculation but from an economic premise shaped by the maximin principle—the notion that no sovereign actor should suffer concrete harm as the result of another's science diplomacy activities or technological products resulting from scientific development.

This approach liberates practitioners from the futile search for hidden motivations. In a world marked by contextual fluidity, shifting alliances, and complex actor constellations (Di Iorio 2022; Luhmann 1996), the more relevant question is not why others act as they do, but how their actions alter outcomes for all involved. Moreover, in the stochastic domain of technology, where breakthroughs often depend on serendipity and investors' volatile capital, efforts to estimate which party will gain more from collaboration are inherently speculative (Rabin 1993). Within the STI ecosystem, results may lead to civilian innovations, military tools, or repressive technologies that can be scaled up immensely—often in unpredictable ways.

Applying Hirschman's options, then, is far from straightforward. It requires observing and interpreting the conduct of multiple actors—scientists, policy-makers, business leaders, and intermediaries—often spread across different states or international organizations. Evaluating science diplomacy decisions demands a layered perspective: immediate rewards and losses (e.g., reputational shifts, funding access, technological application) must be weighed alongside long-term consequences that can differ across actor groups. Amid this complexity, one principle remains constant: responsibility. Effective application of Hirschman's heuristic depends foremost on domestic coordination—the ability of research-performing institutions, funding agencies, and political decision-makers to act coherently when formulating or responding to science diplomacy strategies.

4 CONCLUSION: A REALIST ETHIC FOR SCIENCE DIPLOMACY

In an era of geopolitical aggression, private tech oligarchy, and resurgent authoritarianism, the global role of science, technology, and higher education has never been more paradoxical. These sectors generate the knowledge, talent, and technological breakthroughs essential to shared prosperity—yet they also produce the very key technologies that fuel power competition and, in some cases, repression. Collaboration, open science, and social responsibility remain aspirational norms, but their implementation is fraught with moral tension and strategic risk. The same instruments that address planetary crises can strengthen authoritarian control or upset competitive balances. As we have witnessed, decades of hopeful—if at times naïve—civil engagement in science can collapse within few Russian months, just like the entire value edifice of a glorified liberal democracy might do within the next three years.

Against this backdrop, science diplomacy must reconcile ideals of open exchange with the imperatives of security and national interest, whether one likes or loathes this idea. Upholding the norms of free, secure, and responsible science requires a clear-eyed appreciation of counterpart intentions and the potential externalities of cooperation. Ironically, these noble norms appear most sustainable when grounded in a non-normative model—an economic maximin logic that favors minimizing harm over maximizing gain (Flink 2022).

The proposed heuristic of this chapter provides precisely this kind of pragmatic realism. It enables practitioners to explore courses of action under duress and to anticipate outcomes that balance self-preservation with collective responsibility. For scholars, it offers a structured lens to evaluate whether national STI systems can articulate coherent domestic strategies while engaging volatile or hostile partners abroad. Far from displacing existing science diplomacy frameworks (Flink and Schreiterer 2010; AAAS and Royal Society 2010), this heuristic complements them. It bridges the foreign and domestic dimensions of action, connects science to its political and economic externalities, and invites a more realistic reflection on how—and under what conditions—international scientific relations can endure in a geopolitically strained world.

Given these new realities, science diplomacy needs fresh professional profiles and training. Diplomats must master science, technology, and economics; stay passionate about emerging trends; and think analytically across complex systems. They should navigate both academia and the start-up world with ease. What's needed is a sharp, strategic mix—lawyers who know government, tech geeks who drive innovation, and scientists who understand the culture of research (Su et al. 2024; Melchor 2020). Science diplomacy can no longer cling to the rituals of old protocol or the comforting myth of effortless cooperation. The age of easy consensus is over. Only by facing this reality can its actors think strategically and respond with the clarity and foresight Hirschman imagined.

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Science Diplomacy in the Gap of Uncertain Technological Disruptions

Sercan Sever and Armin Grunwald 

1 INTRODUCTION: FROM TECHNOLOGICAL DISRUPTIONS TO SCIENCE DIPLOMACY

What do we know about the effects of potentially disruptive technologies on society, economy, and politics before the technology is fully developed and widely distributed? Addressing this question is essential for discussing science diplomacy in a rapidly changing technological landscape. In this chapter, an understanding of technology development, technological innovation, and technological disruption (more appropriate: technology-induced disruption), and the associated lack of knowledge about their effects will first be clarified, in order to reflect on implications for successful—means resilient to disruption—science diplomacy.

This chapter does not adhere to a concrete political science framework regarding what science diplomacy is or should be in a crisis-ridden world. It is not denied that these considerations are important for science diplomacy in the midst of and after the *Zeitenwende*, which increasingly is understood as to be a part of interest-led politics (DAAD 2022, 6, 9). However, this work does not aim to challenge or criticize existing approaches to science diplomacy, such as the framework established by the Royal Society's 2010 publication, which distinguishes between “science in diplomacy”, “diplomacy for science”, and

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J. Lüder, M. Wählisch (eds.), *The Palgrave Handbook of Science Diplomacy*,
https://doi.org/10.1007/978-3-032-29473-9_5

“science for diplomacy” (Royal Society 2010). There is already a vibrant debate within the community regarding the development of definitions and approaches. For example, the publishers recently noted that back in 2010 they did not focus “on the role that industry and technology can play in science diplomacy” (AAAS and Royal Society 2024).

This chapter aligns with the ongoing discourse in the field of science diplomacy, contributing to a deeper understanding of the subject. In this way, the chapter attempts to catch up with the “revision” in science diplomacy: science diplomacy should not be understood in isolation from the epistemic core elements of technological change but should be discussed in close relation to them—whether it concerns “science in diplomacy”, “diplomacy for science”, or “science for diplomacy”. It seeks to explore science diplomacy through a specific epistemic lens focused on technological disruption. This change in the discourse—emphasizing technology’s centrality—is crucial. Otherwise, there is a risk of underestimation of the influence of technology development and its uncertainties and complexity on science diplomacy, as well as a risk of an overestimation of science diplomacy as untouched by technological-driven features. The chapter aims to provide a discussion of technology developments and their implications for science diplomacy, starting with a critical epistemic aspect: the inevitable gaps in knowledge that are inherent to technology development.

2 INEVITABLY MISSING KNOWLEDGE AS INHERENT TO TECHNOLOGY DEVELOPMENT

In technology development projects, technologies are developed in a future-oriented manner, because temporalization in the sense of futurization is inherent in every development process: something necessarily develops into the future from today’s point of view. Thus, technology development tautologically has to do with the future that it wants to shape. This future is not determined, but open. Otherwise, there would be no possibility of shaping it: everything would already be fixed, designing would become a nonsense activity. However, this open reference to the future also results in a fundamental uncertainty in the concrete steps of technology development: after all, the future to which actors in technology development refer in their decisions does not, not yet or basically never exists: “the future cannot begin” (Luhmann 1976). Seen from today, it is only fictitiously “there”; if it becomes reality, it is no longer the future, but already the present.

What does this mean for decisions in general, and those of technology development in particular? It is always necessary to operate with imaginations and probabilities of the future. When decisions are made in the context of technology development, the openness of the future must be artificially reduced to such an extent that decisions can be made on the basis of a “fictional expectation” that arises in this manner, “*as if* the future would unfold in the assumed way” (Beckert 2015, 31, emphasis in original): “surplus possibilities have to be reduced as we approach them” (Luhmann 1976, 141). Forecasts, scenarios,

simulations, but also imaginations, hopes, and fears are examples for such kind of fictional reductions. Through this process of reduction, decisions are made possible, especially those in the context of planning and development design. So, decision-making refers to a future artificially reduced by decision-makers and developers and made “certain”. “Knowledge” about the future emerges that only serves the ability to make justifiable decisions (Sever 2024, 303). This knowledge does not promise empirical certainty. It is a knowledge in quotation marks, an uncertain “knowledge” of the future. Thus, “the fundamental uncertainty of human action must be recognized in principle” (Grunwald 2009, 4), because if the fictional expectation of future is only an uncertain knowledge of the future, then it must be clear that everything can also turn out quite differently than expected: The decision on the basis of a fictional reduction can produce different results than the intended ones. So, the “appearance of unintended [...] secondary consequences in the consequence of intentional actions generally belong to every human action” (Grunwald and Julliard 2005, 149). Of course, these possible side effects can and are also considered in decision-making processes: At best, decisions are made so that they do not only produce desirable results in one or two future scenarios but are valid for a whole bundle of possible futures. But the uncertainties cannot be completely eliminated as a result. At some point in the decision-making process, possible scenarios and options have to be dropped. If one tried to take into account all conceivable possibilities of the consequences of a decision, one would never come to a decision.

This describes the first half of the decision-making cycle (Grunwald 2019, 94): (1) Uncertain future possibilities and expectations (van Lente 1993) orient technological design decisions of the present; whereby inevitable missing knowledge is inherent to technology development. This happens by integrating future imaginations into assessments and reasonings in the present, which allows us to make (better) decisions: We evaluate and compare alternatives, reflect on consequences and their degree of desiredness as well as on helpful measures, and finally decide on one to achieve the desired future.

3 INEVITABLY SOCIOTECHNICAL COMPLEXITY AS THE ENVIRONMENT OF TECHNOLOGY DEVELOPMENT

With the lack of knowledge about the open future, the epistemic decision-making situation in technology development has not yet been fully described. There is something else that makes the “better” decision even more difficult for all cases: the inevitable sociotechnical complexity, which is the environment of technology development (Sever 2024, 241). The key word here is socio-technical. This concept draws attention to the fact that the distinction between society and technology is no longer easily tenable in view of today’s progressed coupling of human and non-human entities. A distinction that is common in everyday life can only roughly serve to emphasize rather social, supposedly genuinely human, and non-social, supposedly genuinely technical, aspects, but

cannot fully grasp the sociotechnical totality that has emerged (Ropohl 2009, 92), because it is well known that the whole—sociotechnical reality—is more than the sum of its parts—society and technology. In the meantime, various concepts from different disciplines with the purpose of adequately describing phenomena of the social-and-technological whole emerged: postdigital, onlife, sociomaterial, materialssemiotic, naturecultures (Macgilchrist 2021, 660). More important than the commitment to a specific terminology is that it requires a “contemporary complex understanding of technology, which above all helps to understand sociotechnical complexity” (Gransche 2015, 27). Terms such as sociotechnical can help to grasp the irreducible and non-simplifiable (Gransche 2015, 23) “network of interdependence relations that encompass societal practices on the one hand and material and social techniques on the other” (Grunwald and Julliard 2005, 152). If one fails to recognize the socio-dimension of the technical or the technical dimension of the social, an impossible reduction in complexity becomes possible, whereby only a shortened view and an incomplete knowledge and ultimately unfortunate offers of interpretation and development can be favored.

This insight is not only theoretical but also has an impact on the scope of decisions, because the sociotechnical complexity of the present has indirect consequences for the future—through actions in it. In addition to the missing knowledge resulting from the reference to the future, there is also the sociotechnical complexity that can give rise to potential disruptions from the results of technology development. This describes the second half of the cycle (Grunwald 2019, 94), namely that technology development decisions are made in the present that have uncertain consequences in the future. It is not only the fictionally reduced future that is uncertain at its core (1), to which decisions refer, and which provides orientation for the present. The consequences of the decisions made in the present (2) are also uncertain. We neither know if our expectations, fears, predictions, or narratives of the future will match with the desired future based on our decision, nor if our decision will have any or the desired effects, because we cannot grasp the whole sociotechnical complexity while deciding. We only can focus and work on partial aspects and are dependent to (insufficient) data we have, which necessarily leads to unforeseen future results, because we had to ignore other partial aspects while deciding.

So far, we can state: “In technology development, which is permeated by not knowing, not yet knowing and unknown not knowing, uncertainty is a constant companion of decision-making processes” (Schönewolf 2020, 43). There is always uncertainty about (among others),

- whether the technology development undertaken for creating an innovation will be successful (there could be unforeseen technical problems),
- whether the planned innovation will ultimately be an innovation (it is possible that other actors will beat the entrepreneur to it),
- whether the innovation will be accepted by the target group (there may be no interest on the part of consumers),

- whether the innovation will have—if accepted—the intended effects, or whether other and/or additional consequences will occur, possibly causing harm and risk,
- whether the innovation will be used in the intended way (consumers may discover a critical side function, or the innovation could be subject to dual-use or multiple-use),
- whether the *ceteris paribus* conditions assumed during innovation development remain in place (disruption may occur at an early stage, before the development is completed).

4 TECHNOLOGICAL INNOVATION VS. TECHNOLOGICAL DISRUPTION

The outlined understanding of technology development now provides clues as to how innovation and disruption should be thought of in view of the complexity of the present and uncertainty about the future, in order to be able to derive implications for science diplomacy in an era of technological disruptions. Two notes in advance: (1) Only innovations of a technological-artifactual nature are considered; although innovations do not necessarily have to be of this kind (Blok 2023, 10). Other forms of innovation that come about outside the technological-artifactual (e.g., political, cultural) are not taken into account. (2) In this chapter, (technological) innovation is placed in the context of (technology-induced) disruption. This connection goes back largely to Schumpeter (1943, 1983), who is considered one of the “founding fathers” of a techno-economic understanding of innovation and an understanding of disruption that revolutionizes the market but preserves the economic system (Blok 2021, 76–80).

According to the Cambridge Dictionary ([n.d.](#)) disruption means “the action of preventing something, especially a system, process, or event, from continuing as usual or as expected”. The origin of the word sounds more negative: *disrumpere* (lt.) as to break, to burst, to tear. The word field of unexpected, profound change also encompasses semantically similar terms to that of disruption: crisis, catastrophe, collapse. The advantage of the word “disruption” is that it is more connotatively diverse, can be used both for positive and negative connotations, and for description.

According to Schumpeter, disruption occurs after the successful distribution of an innovation when the politico-economic status quo is interrupted to the advantage of the developer of the innovation, that is, the entrepreneur achieves a monopolistic position while preserving the capitalist system (Blok 2021, 77–78). A typical example is the innovation of the diesel engine, which led to disruption: “The innovation of the diesel engine in locomotives, for instance, was not just the creation of a new technology but also the destruction of the existing industry in steam engines, just like the innovation of the compact disc destroyed the industry of cassette tapes and LPs and has now been replaced by MP3 and streaming services” (Blok 2021, 78–79). It is not the technical

artifact itself, the innovation, that is disruptive. The technical artifact is “only” an innovation that can result in disruption if it releases sociotechnical dynamics that lead to the widespread replacement of other artifacts (former innovations) and their value, to the reformation of artifacts and their modes of appearance in an associated politico-economic order, and to the strengthening of new actors while retaining—according to Schumpeter—the capitalist system: “What is destroyed by the innovation of streaming services is not so much the CD in the literal sense—there are still CDs in the world—but the way value is created and captured via markets in the economic order associated with digital networks like the internet” (Blok 2021, 86).

The aforementioned disruptions had not been recognizable in advance, let alone intendedly brought into appearance, nor were the winners and losers to be determined *ex ante*. Only in retrospect—*ex post*—does it become possible to name the catalysts, to describe the factors, which led to the disruption. This is also the case with current innovations that may lead to future disruption: they are not yet or never completely demonstrably disruptive in the present. As soon as evidence can be provided, that is, path dependencies can be empirically proved, and an ongoing disruption can reliably be assumed, then one already finds oneself in these empirically proved dependencies. From this point of recognition of the dependencies already involved in them, it is hardly possible to step out of the path of technology development and technology distribution that is already underway, even if it proves to be a path full of negative consequences. This phenomenon is sufficiently known as the Collingridge dilemma (1981):

In early stages, much is naturally open and statements about future developments tend to remain speculative. Many merely possible developments interact in an unknown future with other merely possible developments in an unknown way, creating an epistemological mixture of high complexity and uncertainty. As developments progress, the data situation will improve and the epistemic evidence will increase, because the effects will become more visible, and the scientific understanding of the connections will become more profound.

—but then the process is not as good to readjust as at the beginning of development (Grunwald 2023b, 451). If a so-called *point of no return* has not yet been reached, countermeasures can still be taken in the event of a fatal disruption that is likely to occur. However, it is “difficult, if not impossible, to recognize the point in time in the gradual development at which the fatal path dependency sets in, the tipping point is exceeded and a development like many others becomes a development with the potential of dystopian disruption” (Grunwald 2023b, 454).

On the one hand, future “knowledge” about the consequences of an innovation is therefore useless for recognizing disruption, as it is all too partial, limited, reductionist, and shortsighted. On the other hand, it is only a “knowledge” of the future as non-knowledge that promotes disruption that could

otherwise be forestalled (if negative effects are feared) or accelerated (if positive effects are hoped). To conclude, the most important feature of potential disruptive processes like emerging technology development projects remains their uncertainty. Uncertainty is twofold technology-induced disruptions inherent: first as uncertain results, and second as uncertain consequences of the uncertain results. This means, we know neither the innovation output, nor the innovation process, its sociotechnical impact, and their consequences beforehand. This is fundamental to technological (induced) disruptions that science diplomacy has to deal with.

5 IMPLICATIONS FOR SCIENCE DIPLOMACY: THE AUTONOMOUS DRIVING EXAMPLE

Currently, this situation of double uncertainty leads to high restlessness in the automobile industry. The big automotive companies in various parts of the world, for example, in Japan, China, the United States, and Germany, have to deal with extremely high uncertainties of future mobility. The combination of possibly disruptive effects of self-driving cars (Maurer et al. 2016), the turn to e-mobility due to climate change issues, and the uncertain future of fossil-driven cars created an atmosphere of deep concern about future developments and the loss of planning certainty. For example, German companies which are strong in the traditional way of building cars are afraid of disruptive developments due to technological innovation in other world areas, on the one side, and unforeseeable regulatory issues, on the other. Obviously, such situations are challenges to science diplomacy, in particular if they are accompanied by “races” of competition like in the fields of AI, autonomous driving, and quantum technologies. They are challenging, because (to name some aspects for autonomous driving according to the uncertainty list mentioned in “Inevitably Sociotechnical Complexity as the Environment of Technology Development”).

- it is uncertain whether the technical infrastructure for autonomous driving can meet all the requirements necessary to establish a new, successful system comparable to the existing driver-based infrastructure, regardless of industrial and investor promises and of cultural differences, for example, between the road traffic in Phoenix (AZ), European medieval cities, and megacities in Asia or Africa,
- it is, in particular, uncertain whether the technology will be able to manage unexpected situations in the complex traffic mix in urban systems, composed of autonomous cars, traditional cars, bikes of different kinds, pedestrians, areas of construction, adverse weather, and sight conditions, and so on,
- it is uncertain how the public, the media, and possible users of autonomous cars will react on possible series of accidents, in particular of fatalities—the only thing that is sure is that mass media will make big stories of such events,

- there is no guarantee that other, currently unknown or less-publicized projects, and alternatives will not preempt the efforts of entrepreneurs in the autonomous driving sector,
- it remains unclear whether the target audience will transition to autonomous driving due to factors such as safety concerns, cultural preferences, psychological issues, financial considerations, or established habits,
- the extent to which autonomous vehicles will produce the intended quantitative and qualitative effects—such as changes in mobility patterns, economic growth or decline, environmental impact, and accident rates—remains uncertain,
- it is uncertain if autonomous driving will be adopted for mainly the same reasons as traditional driving, or if the chance of autonomous driving could turn to danger and be undermined by issues related to manipulation, misuse, and crime,
- it is unclear whether future conditions—such as market dynamics, social factors, energy availability, and legal frameworks—will remain stable or if disruptive events (e.g., wars, pandemics) will arise and possibly heavily affect the future mobility sector, in particular its high-tech end.

Given the inevitably missing knowledge, sociotechnical complexity, and the “nature” of technological innovations and their potential, but hence unknown, disruption capacity, we can articulate some implications for science diplomacy. If science diplomacy wants to be resilient against the background of technological disruption, it should be aware of these implications. At least five implications can be described: (a) steady epistemic insufficiency, (b) modest decision-making, (c) public involvement, (d) shared responsibility, (e) reflective collaboration.

- (a) It should now have become clear that future-oriented developers, but also scientists, entrepreneurs, and other social actors, have to deal with many uncertainties regarding technology development that cannot simply be eliminated. From this must be derived an awareness and real recognition of what we know, what we can know, and what we cannot. In this respect, the individuals and collectives of the world society are epistemically at the same starting point: From an epistemic point of view, everyone being part or not part in the technology development process knows more or less the same about the future of its outcome and effectiveness in terms of non-, utopic, or dystopic disruptions.

Sometimes, however, actors perform speech acts as if they knew to a degree of complete certainty how particular innovations would have an impact. Here it must be assumed that this is done out of deterministic belief systems, ignorance in the sense of an unknown ignorance, or for the purpose of persuasion to promote technology projects and profitably implement one’s own products. Such speech acts about the future, which are certainly and conscientiously presented, are not to be under-

stood as epistemic statements, but only as rhetoric or purpose-bound, because the state of “epistemic insufficiency” cannot simply be left (Blok and Lemmens 2015, 32). “In all attempts to communicate, one can assume the uncertainty of the other” (Luhmann 1992, 141). So, no matter which speech act games are presented and played, the uncertainty does not change. Actors who are active in science diplomacy should not succumb to these speech act games, otherwise they would have to be accused of similar ignorance and purposeful intentions, which would affect the credibility of an informed and reflective appearance, which would be fatal for a science diplomacy that disputes serious concerns. Science diplomats, who do not serve as entrepreneurs or investors in their professional roles, should differentiate between industrial hopes, fears, and promises, and probable and desirable future outcomes for the world society. Their responsibilities extend beyond economic interests; they ideally act in the best interest of the global community. When discussing initiatives related to autonomous driving at international conferences with the participation of science diplomats, they should clarify what are promises from the industry and what are other desirable futures. They should make it clear that economics is one area of expertise among others when it comes to making decisions about the future. They should not equate economics with other areas of expertise.

- (b) Despite epistemic insufficiency, decisions must be made. It is not enough to talk about all possible options. One cannot just retreat to an external location and observe from there without acting. One lives and acts “always in the participant’s perspective with creative possibilities or necessities” (Grunwald 2012, 106). Decisions do not come to a standstill; decision-making never stops. But there is a “but” that is particularly valid for science diplomacy if it wants to come across as credible: In view of the state of fragile knowledge, the type of communication and decision-making should be fundamentally modest in two ways. First, communication about technology developments should be done with an emphasis on the uncertain state of knowledge. In this respect, a modest appearance should not be understood as an unsettled appearance or as belittling one’s own positions, but as an honest and self-confident drawing attention to the many elements of missing knowledge that surround us even in critical decision-making situations, which should not be underestimated at all. Second, the scope of the decisions should be modest. Large global and now space encompassing projects should only be scheduled to the extent that no irreversible damage occurs, no points of no return can be reached, or at least only be accepted, if they are really well thought out. According to the experience of recent years, everything else, such as projects that are based on the principle of trial and error, should be avoided. “Anthropogenic climate change is an example of this: serious damage

is already happening today, and the path dependence of the global economy has so far led to continuous ever-worsening despite all countermeasures” (Grunwald 2023b, 453). Science diplomats should advocate for thorough consideration of the consequences of technological development before major agreements are made, and they should refrain from making decisions without a clear negotiation and deliberation on those consequences (Fleischer and Schippl 2024). For autonomous driving, or for the future of mobility in general, this means that they should encourage reflection on the consequences across as many relevant societal areas as possible, rather than focusing solely on economic figures.

- (c) Precisely because the development of technology has recently affected all individuals and collectives in world society, it “can no longer be understood as the domain of individual inventors and entrepreneurs but is increasingly taking on the character of a public affair” (Ropohl 2009, 284). This means that society is not only becoming more important as an object in research and application issues, but also as the accurate place of understanding: “it is the complexity of the grand challenges and the uncertainty of the future impact of our innovations which calls for a continuous enactment of the dialogue with the other” (Blok 2014, 184). In this perspective, there are fewer questions about unidirectional dissemination, the presentation of results that have already been defined, the polling of opinions on finished development results, or the subsequent acquisition of acceptance for technical innovations, but rather about integration into the research and development process itself as participants on an equal footing. Effective policies can be implemented if the following conditions are met: “open institutions and a problem-solving culture based on conceptual coherence, shared values and practices amongst scientists, diplomats, legislators, and policy practitioners” (Lüder 2024, 1).

The scope of the technical results requires the involvement of many actors, including non-scientific ones—even if this involves dangers (Crabu et al. 2023, 595). Science diplomacy can demand this on an international stage of politics, research, and business, referring to knowledge theory and social science findings on participatory technology development. Following Doorn’s overview (2012, 204), this includes approaches such as Constructive Technology Assessment (Schot and Rip 1997) and Participatory Technology Assessment (Joss and Bellucci 2002). There are a lot of concepts reflecting the possibilities of transdisciplinary, multiactorial involvement in the technology development (Grunwald 2019, Grunwald 2024b). To achieve this, science diplomats should not only involve governmental and supranational institutions but also actively seek and engage civil society actors who typically participate more in domestic rather than foreign policy discussions, including those related to the future of mobility.

- (d) In the highly complex network of all participants, the question of responsibility for the course of technology development cannot (any longer) be attributed to a specific actor alone: “The causal condition for responsibility is rarely met in innovation as a multiplicity of actors is involved and there are long causal chains between the innovation process and the eventual social impacts” (Sand and van de Poel 2021, 4776). The inclusion of many actors may therefore lead to attribution difficulties—but not to attribution impossibilities. This does not mean that the responsibility for the course of technology development dissolves in the crowd of participants. Rather, the responsibility is now more divided among them. Technology development is the responsibility of all parties involved in phases: “The paradox is that no one actor is in control, but everyone is implicated, has agency and therefore is responsible, interconnected in complex networks, at multiple scales, and in numerous ways. [...] However, the fact that everyone is implicated does not mean that there is horizontality, but instead that hierarchies are interconnected in complex networks, at multiple scales” (Azevedo et al. 2014, 195–196).

Recently, the research strand of Responsible Research and Innovation drew attention to this. One of the mainstream approaches in this strand of research is that of Macnaghten, Owen, and Stilgoe (2013). By responsible innovation, they mean “taking care of the future through collective stewardship of science and innovation in the present” and propose four “heuristic helpful” dimensions by means of which “a framework for raising, discussing and responding to such questions” is provided; these are: “anticipation, reflexivity, inclusion and responsiveness” (Macnaghten et al. 2013, 1570). While recognizing sociotechnical complexity and future uncertainty, the respective shares of responsibility in the development process are seen in a distributed manner (reflexivity) and thus the assumption of responsibility (responsiveness) of all those involved is sought (inclusion) and formulated in order to be able to gain epistemically useful and ethically qualitative knowledge (anticipation). Science diplomacy can build on Responsible Research and Innovation concepts and take responsibility in the field of technology development. On the international stage, science diplomats can pay attention to the distribution of responsibility and participation in responsibility and strive to reduce the difference between power-political agitation and withdrawal from responsibility. In the context of autonomous driving, science diplomats can clarify the responsibilities of those involved. They should emphasize the importance of not waiting or simply continuing until the data is flawless, as this could mean surpassing the tipping point and potentially reaching a point of no return. The possible futures of autonomous driving (Maurer et al. 2016) must be reflected upon and discussed now, even if they are not yet a widespread reality. If signs of danger from autonomous driving become

more pronounced, steps must be taken immediately to address these issues. Due to their role as intermediaries, science diplomats should take a more prominent stance in addressing these steps.

- (e) If one considers the uncertainty of the future and the sociotechnical complexity as well as the shared responsibility, it becomes all too clear that in any case a reflective understanding between states, institutions, and the various subsystems of society is necessary in order to achieve meaningful decision-making with resilience in the age of technology-induced disruptions. This is an ethical challenge: mere suspicions of dystopian disruptions are “not sufficient for the initiation of far-reaching measures with, for example, considerable resource requirements, burdens or restrictions on freedom” (Grunwald 2023a, 26). Science diplomacy must think carefully about the tone it chooses in order to reflect on the problems and opportunities of technology development:

On the one hand, there is trivialization and appeasement with the reference that we have to wait for better data, that it is too early to act. On the other side, there is an urgent call for measures that it could otherwise be too late. Mutual accusations of exaggeration, ideology, speculation, trivialization, whitewashing, irresponsibility or insinuation of hidden interests are the result. (Grunwald 2023a, 26).

Instead of attempts to simplify sociotechnical contexts and attempts to reassure the future, the negative consequences of increases in uncertainty can be counteracted by jointly establishing “socially robust knowledge” (Nowotny 2003). A rejection of this understanding may be echoed in scientific and technocratic visions, but it testifies to an inadequate understanding of complexity, of only fictional knowledge of the future, of the epistemologically equal starting point of scientists, entrepreneurs, citizens, and politicians, and of the responsibility shared by all. Reflective understanding and collaboration requires.

careful consideration and consultation, the weighing of alternatives, the search for the right measure and ethically legitimized criteria [...]. All this takes time in two ways: on the one hand for the consultation and consideration processes themselves and on the other hand for the implementation of the results in practical decisions. (Grunwald 2024a, 427–428; Grunwald 2024c).

In case of doubt, if not enough time is granted for reflective collaboration, it is still necessary to “increase everyone’s uncertainty so that one can only communicate”, because “communication aimed understanding must [...] first of all, increase uncertainty and cultivate the common knowledge of ignorance” (Luhmann 1992, 197).

The insight into collaboration can succeed not only through highlighting the uncertainty of future “knowledge”, but also through a revaluation of uncertainty itself, from which ultimately creative potential only grows.

Uncertainty is an ambivalent, non-eliminable fact of human existence: “One can only decide if it is not certain what will happen” (Luhmann 1992, 136). The “uncertainty of future knowledge” is not only part of “fundamental structures of human and society and is therefore insurmountable”, but it is also an “expression of the ability to shape the future” (Grunwald 2018, 59). Uncertainty brings us trouble, but also the chance for an epistemic equality and the recognition of dependency and collaboration. This should be the frame for understanding and communication within science diplomacy, since there is no way out, no option of being unaffected, independent or superior in the light, more appropriate: in the gap of uncertain technological disruptions. Science diplomats are professional communicators who excel at fostering collaborations. This skill creates opportunities for dialogue that are essential for other key individuals in the development process, such as engineers, scientists, and investors. For instance, they can facilitate discussions about the future of mobility in a way that is both internationally reflective and integrated.

6 CONCLUSION

As can be seen, relatively little is known about the impact of potentially disruptive technologies under development due to future uncertainty and sociotechnical complexity. In this chapter, an attempt has been made to derive implications for science diplomacy on the basis of this finding. The nature of technology-induced disruption brings a gradual (Grunwald 2023a), surprising, and profound change. Missing knowledge is the most important epistemic feature from which a framework for addressing challenges in science diplomacy can be considered. In order for science diplomacy to succeed against this background of ignorance in technological change, that is, to be resilient to unknown disruptions and to be able to act, five implications are suggested—according to the proposal here—that should be taken into account. It is important to (a) take the steady epistemic insufficiency seriously and not to succumb to nonsensical rhetoric of false certainties. It is important to (b) make modest decisions in order to prevent irreversible damages. Furthermore, (c) a large number of affected and involved parties should accompany the technology development, among whom (d) the responsibility is distributed. Overall, the process of science diplomacy under the highly complex and uncertain circumstances (e) must be reflected and collaboratively contested. This may not prevent undesirable disruptions, but one would have taken the minimum into account what would be necessary to cope with them.

One may be surprised that no direct solutions for science diplomacy have been offered here, but only uncertainties have been pointed out, and implications have been named. But where there are no certainties, none can be conjured up. This is a direct implementation of the implications (a) and (b). Such activities of pointing out uncertainties are also part of science and also of science diplomacy: “science not only provides solutions and certainties, but its

findings also create negative externalities and uncertainties” (Flink 2020, 365). Even if security concerns and systemic rivalry are likely to play a superficial role in science diplomacy since the *Zeitenwende* at the latest and in the near future, the ideal of collaboration should be adhered to and threads of conversation should not be broken (further), if we want to be able to overcome future technological challenges as a global society (Eigner 2023, 4). On the “how”, science diplomacy itself still has to decide.

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Revisiting Scientific Uncertainty in Science Diplomacy on Emerging Climate Technologies

Finja Isabel Augsburg 

1 INTRODUCTION

Goal 13 of the United Nations Sustainable Development Goals (SDGs) calls for “urgent action to combat climate change and its impacts” (United Nations [n.d.-b](#)). With effects ranging from extreme weather conditions to rising sea levels and food insecurity, climate change is the “defining issue of our time” (United Nations [n.d.-a](#)) that we face at a defining moment (United Nations [n.d.-a](#)). This chapter is based on four essential premises:

1. First, that climate change is a global threat that requires to be approached across national boundaries (German Academic Exchange Service [2022](#); The Royal Society [2010](#)).
2. Second, that responding to challenges posed through climate change significantly depends on advancements in science and technology (World Economic Forum [2023, 2024](#)).
3. Third, that the integration of scientific knowledge¹ into policymaking processes is increasingly essential for the effective formulation and imple-

¹ This chapter conceptualizes uncertainty as an inherent aspect of scientific knowledge, emphasizing empirical observation and the provisional nature of evidence. While other knowledge systems (such as Indigenous knowledge) contribute significantly to climate policy, this chapter is grounded in the framework of Western scientific traditions and adopts an atheistic perspective.

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mentation of climate change mitigation strategies (The Royal Society 2010; Dhar and Srinivas 2023; Schneider 1989).

4. Fourth, that policymakers must navigate an increasingly complex and uncertain nexus of science, technology, and innovation (STI) (Benessia and Funtowicz 2016; McEvoy and Wilder 2012; Abreu and Andrade 2019; OECD 2023b).

These premises imply that effective policies to address climate change require collaboration across disciplinary and international frontiers at the intersection of science, technology, and foreign diplomacy. For this dynamic, science diplomacy plays a central role. It aims to advance international cooperation to address global challenges by creating constructive, knowledge-based partnerships between countries and fostering joint commitment to a sustainable future (The Royal Society 2010; German Academic Exchange Service 2022). Intensive dialogue described as a “feedback loop” (Dhar and Srinivas 2023, 25) sets the framework for such action: Science provides the knowledge and tools to address global challenges and forms the supply side (Lüdert 2024; Dhar and Srinivas 2023). Diplomacy, on the other hand, constitutes the demand side of policymakers and governance institutions, using the knowledge to engage in international academic cooperation and policy formation (Dhar and Srinivas 2023; Lüdert 2024). This dynamic is central as decision-making takes place in an increasingly complex world, particularly driven by rapid and disruptive technological development (Schuelke-Leech 2021; The Royal Society 2010). The latter, however, is crucial for responding to climate change (Federal Ministry of Education and Research n.d.).

STI and science diplomacy. Disruptive technologies such as nanotechnology and environmental biotechnology are key contributors to sustainable development in the face of the far-reaching global impacts of climate change (Thiele 2020). The disruptive nature of these technologies is due to their non-linear growth and their potential to drive fundamental transformation. As emerging technologies, they enable the generation of entirely new perspectives, scopes for action (Schuelke-Leech 2021; Socol et al. 2023; OECD 2013; U.S. Department of Agriculture n.d.) and “significantly impact climate adaptation and mitigation efforts” (Thiele 2020, 521). In the field of STI, science diplomacy is yet a fluid concept that involves three dimensions: *diplomacy for science* (fostering international academic cooperation), *science for diplomacy* (using international science cooperation to improve relationships between countries), and *science in diplomacy* (direct scientific contribution to foreign policy objectives) (The Royal Society 2010). What we know from previous work on science diplomacy is that it can both maximize the opportunities and mitigate the challenges that come with technological progress, while enabling solutions to global challenges such as climate change (Colglazier 2018). This perspective is not an entirely novel one: In the reports of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, Principle 9 posed that “States should cooperate to strengthen endogenous

capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies” (United Nations 1993, 4).

Scientific uncertainty. In times of increasing complexity of research and evidence on climate change, accompanied by rapid technological progress to advance solutions, policy decisions informed by scientific information must be made in a context of uncertainty (Bradshaw and Borchers 2000; OECD 2013; World Economic Forum 2024). However, “policy makers, like most people, dislike deep uncertainty: they prefer to be in situations where they know the probabilities of given events or actions” (Berger and Bosetti 2020). Deep uncertainty describes a state of disagreement about the likelihood of future scenarios (United States Global Change Research Program 2021). It is one among many manifestations of the larger concept of scientific uncertainty, defined as “a state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable” (IPCC 2015, 128). The basic principle of the concept is that scientific knowledge is inherently uncertain, with “new information continually altering our perceptions and beliefs” (Bradshaw and Borchers 2000). Scientific uncertainty figures prominently in the context of policymaking on environmental issues, where its perceived role and function has been subject to an ongoing transformation. Uncertainty in science can take different forms: Gustafson and Rice (2019) distinguish between (1) knowledge gaps, that is, a lack of evidence on certain questions, (2) technical uncertainty due to methodological and statistical reasons, caused, for example, by sampling errors, (3) a lack of consensus, that is, ambiguous or contradictory results and scientific controversies on a topic, and (4) the fundamental uncertainty that scientific findings may turn out to be wrong in the future. A further distinction can be made between different levels of uncertainty. Issues such as climate change are at the highest level as situations in which one “is still able (or assume) to bound the future around many plausible futures (4a) and situations in which we only know that we do not know (4b)” (Marchau et al. 2019, 8). This demonstrates that scientific knowledge and assessments of developments, impacts, and responses to the challenges posed by climate change are inevitably subject to scientific uncertainty (Funtowicz and Ravetz 1990; Bradshaw and Borchers 2000; Curry and Webster 2011; OECD 2023a). And this is the pivotal point—it is at this juncture where uncertainty as an inherent element and fundamental driver of scientific progress on the supply side coincides with a demand side that strives for clarity over the question of how to address climate change and its impacts based on scientific evidence (Haas 2021; Benessia and Funtowicz 2016; Curry and Webster 2011; Riordan and Jarrín 2020; Meah 2019; McEvoy and Wilder 2012; Abreu and Andrade 2019; Florin 2014; UN Department of Global Communications 2024). As scientific uncertainty affects how knowledge is communicated to decision-makers and the public and influences policy development (Fischhoff and Davis 2014), an understanding of the role it plays and

the challenges as well as opportunities it presents is essential for all actors involved in policymaking, research, and communication (OECD 2023a; Mauduit and Gual Soler 2020; Fischhoff and Davis 2014; Schneider et al. 2022).

This chapter provides a literature-based revisit of the role of scientific uncertainty in science diplomacy and its implications for responses to challenges posed by climate change in an era of technological disruption. Furthermore, by considering functional and dysfunctional patterns in the way scientific uncertainty can unfold, the chapter aims to elucidate the opportunities that can result from the effective handling of scientific uncertainty, which is recognized as both challenging and imperative (Bradshaw and Borchers 2000; Mauduit and Gual Soler 2020). A deeper scholarly examination of scientific uncertainty in reference to science diplomacy on climate issues experienced a period of growth in environmental discourse around the turn of the millennium. However, the increasingly complex and uncertain landscape of climate change research and rapid technological advances call for renewed consideration.

2 SCIENTIFIC UNCERTAINTY IN CLIMATE CHANGE POLICY AROUND THE TURN OF THE MILLENNIUM

Over time, strategies for navigating scientific uncertainty in policymaking have evolved in response to various challenges and crises. Facing increasing environmental threats in the 1990s (Funtowicz and Ravetz 1990), the emergence of the Precautionary Principle and the Post-Normal Science approach brought new reflections on role and the handling of scientific uncertainty to attention. Among the issues addressed were human inputs and environmental impacts, such as those caused by carbon dioxide emissions or the chemical and biological consequences of marine pollution (Stevens 2002; International Maritime Organization 1990).

The Precautionary Principle. The Precautionary Principle was introduced at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 (UN Global Impact n.d.). It is based on the premise that science “can be temporarily unable to produce a conclusive and exhaustive body of knowledge fit to serve as a basis for rational decision making” (Benessia and Funtowicz 2016, 91). While the approach is a subject of ongoing discussion, it is considered a fruitful strategy when confronted with high-stakes scenarios that entail uncertain consequences for the environment or human health (OECD 2023b). The Precautionary Principle emphasizes a link between the political responsibility to act in cases of acute threats to human health or ecosystems and the inherent uncertainty of scientific knowledge about the potential consequences and impacts of such action (Martuzzi and Tickner 2004). Further, it argues that scientific uncertainty should not be used as a rationale for postponing the implementation of measures to prevent damage to humans and the environment (Martuzzi and Tickner 2004). Modifications to this approach have been proposed, particularly with respect to handling scientific uncertainty in technological advancement. The argument put forth by Weiss

(2003), for instance, called for an adaptive approach to ensure that progress is not prematurely abandoned but rather allowed to evolve until its full implications are understood. Given the inevitable uncertainties that arise in the STI field, this was among the early proposals to work with rather than against these uncertainties, and to encourage innovation rather than stagnation (Weiss 2003).

Post-Normal Science. In the face of global challenges, especially climate change, science is increasingly based on “unpredictability, incomplete control, and a plurality of legitimate perspectives” (Funtowicz and Ravetz 1994, 1881), on which the concept of Post-Normal Science builds. It was conceptualized by Silvio O. Funtowicz and Jerome R. Ravetz as a novel approach to developing a new global response to environmental issues that could not be addressed by means of traditional science. In the mid-1990s it considered the management of scientific uncertainty as a central element for progress in this endeavor (Funtowicz and Ravetz 1990). While the Precautionary Principle was built on the belief that uncertainty will sooner or later result in either scientific confirmation or rejection, an alternative perspective emerged around the same time through Post-Normal Science. The approach holds the view that “uncertainty in the context of a techno-scientific issue cannot be treated as an independent variable and reduced linearly, as is the case with the conventional approach in the context of the precautionary principle” (Benessia and Funtowicz 2016, 92). Similar to the Precautionary Principle, however, the concept of Post-Normal Science is frequently considered in situations that require urgent decisions made on an uncertain base of scientific knowledge (Funtowicz and Ravetz 1993, 744).

A fundamental premise of both Post-Normal Science and the Precautionary Principle is the unavoidable confrontation with scientific uncertainty at the interface of science and policymaking when addressing environmental challenges. Further, navigating scientific uncertainty was identified as a significant challenge that policymakers must address in order to facilitate the integration of scientific evidence into policy decisions and effectively respond to climate change (Bradshaw and Borchers 2000).

Assimilation. In the early 2000s, assimilation emerged as a strategy for addressing complex environmental risks that are unlikely to be resolved with scientific consensus and unambiguous guidance at the science–policy interface. Assimilation involved confronting and engaging with what has been metaphorically described as an “uncertainty monster” (van der Sluijs 2005, 89), embodying mutually exclusive categories such as “knowledge versus ignorance, objective versus subjective, facts versus values, prediction versus speculation” (van der Sluijs 2005, 92), which became increasingly intermixed. As a result, the challenge identified was to adapt “the monster, but also the cultural categories by which it is judged” (van der Sluijs 2005, 91) which, in turn, is also a defining feature of the Post-Normal Science mindset. The turn of the millennium gave rise to a pivotal discourse situating scientific uncertainty within a global context shaped by emerging environmental challenges, technological advancements, and evolving international dynamics.

The strategy of assimilation was identified as an increasingly central trend in the following years, with the objective of situating “uncertainty at the heart of the science-policy and science-society interfaces” (van der Sluijs 2005, 87). One of the significant challenges in strengthening these interfaces was to align the definition of scientific uncertainty held by the public and policymakers with that of the scientific community as a means of bridging the science-policy gap (Bradshaw and Borchers 2000). Scientific uncertainty was reframed as a form of knowledge rather than as ignorance. As a consequence, this required a significant shift in perspective for the public and those involved in policymaking, away from the pursuit of deterministic solutions and certainty (Bradshaw and Borchers 2000). Along with these emerging perspectives came a functional view of scientific uncertainty, prompting a differentiated response to the various forms of uncertainty inherent to scientific practice. Over the following years, the prevailing notion was that a significant role in navigating the scientific uncertainty associated with climate change was to be played by collaboration at the national and international science-policy interface (Curry and Webster 2011; Smith and Stern 2011; OECD 2023a). Entering the early 2010s, managing this uncertainty remained a major challenge: In a study by Sutherland et al. (2012), 52 participants from the scientific and policy communities identified 40 key questions in their fields. Among these, scientific uncertainty was highlighted as a significant concern in six questions, such as: “How do policy makers understand and respond to scientific uncertainties and expert disagreements?” (Sutherland et al. 2012, 3), underscoring the persistent need for reflection on the role and handling of scientific uncertainty, especially when a lack of consensus arises within the scientific community.

In summary, the literature reviewed indicates that in the 1990s and early 2000s, scientific uncertainty was perceived as a challenging, but manageable, inevitability in the context of climate-related science diplomacy, with an increasingly functional perspective emerging. Against the above-mentioned background of ongoing discourses, advances, and remaining question marks, this chapter will proceed to address the role and function of scientific uncertainty in the past decade entering an era of technological disruption, with a particular focus on its implications for the practice of science diplomacy.

3 SCIENTIFIC UNCERTAINTY AT THE NEXUS OF SCIENCE, TECHNOLOGY, AND DIPLOMACY IN THE PAST DECADE AND EARLY 2020s

Over the past decade, the science-policy interface has been marked by a three-way dynamic in addressing climate change: Global climate impacts are increasing in severity and complexity (United Nations n.d.-a), the 2030 Agenda for Sustainable Development requires implementation (United Nations n.d.-c), and technological innovations and solutions to address climate change are evolving rapidly (Schuelke-Leech 2021; The Royal Society 2010). This

dynamic both offers an opportunity for effective action and imposes the challenge of navigating a significant degree of uncertainty at all levels involved.

To begin with, the ability to navigate scientific uncertainty has continued to emerge as a fundamental competence in today's climate policy negotiation and decision-making processes. It was already recognized as significant in the early 2000s, but it is now considered to be on par with critical thinking and risk assessment (Mauduit and Gual Soler 2020; The Royal Society 2005). The assessment of uncertainty inherent in a given technology or measure plays a decisive role in whether to pursue or bypass opportunities, resulting in significant risks of missed chances or negative consequences (Fischhoff and Davis 2014). A recent example can be drawn from biotechnology, with a vivid debate over efforts to limit agricultural emissions and improve crop resilience to climate change, particularly through genome-editing technologies such as CRISPR (Savage 2022). In this inherently complex field, new uncertainties and trade-offs arise constantly and challenge the discourse among and between scientists, policymakers, and the public as advances are made (Bouchaut et al. 2022; Wirz et al. 2020). However, this case is not an exception: As climate change progresses, policy-level pressures and uncertainties coincide with scientific uncertainties within the research community, serving as an advisory body (Mauduit and Gual Soler 2020; Haas 2021; Benessia and Funtowicz 2016; Riordan and Jarrín 2020; Meah 2019). The contemporary science-policy nexus is characterized by a strong demand for research input, whereby it is often impossible for scientists to make definitive statements (Piaget 2023; Theokritoff and D'haen 2021). This paradox—where research progresses but uncertainty grows—stems from the nature of science itself: while science works toward reducing complexity, each new discovery uncovers deeper layers of complexity (Luhmann and Behnke 1994), including new uncertainty (Bouchaut et al. 2022). Again, biotechnology serves as an exemplary case here, as new genomic techniques can introduce hitherto unknown uncertainties due to their inherent unpredictability (European Commission 2023; Bouchaut et al. 2022; Wirz et al. 2020).

Considering the role of scientific uncertainty in science diplomacy efforts to shape climate change policy, the Paris Agreement is a prominent and frequently discussed example. The Paris Agreement, facilitated by science diplomacy (The Diplomatic Service of the European Union n.d.), established a framework for immediate international action based on a weighing of inherent scientific uncertainties at the intersection of research and policymaking. The agreement represents a commitment to reduce global emissions and to collaborate beyond borders in adapting to the impacts of climate change. It further demonstrates the impact of the work of the Intergovernmental Panel on Climate Change (IPCC), founded in 1988. In its reports, the IPCC provides a synthesis of scientific evidence on climate change and facilitates the integration of such findings into climate policy (Earth Negotiations Bulletin n.d.). The IPCC has been instrumental in creating the necessary momentum for the implementation of the Paris Agreement, a legally binding international treaty based on the Precautionary Principle, which, as previously stated, is constructed around two

fundamental issues: risk assessment and the closely related management of scientific uncertainty (Crawford-Brown and Crawford-Brown 2011). The latter is particularly crucial as the prediction of climate developments involves a high level of vagueness in many areas due to the complex nature of climate change and its contributing determinants (Ekardt et al. 2018). These include large- to small-scale factors ranging from the overall accumulation of short-lived aerosols, leading to delayed effects of greenhouse gas emissions (Ekardt et al. 2018) to regional emission estimates when zooming in (Rogelj et al. 2017). Based on the analysis of observations, model results, and expert judgment, IPCC reports address the scientific uncertainty connected with assessments and predictions through the expression of qualitative levels of confidence, the degree of consensus among the scientific community, or quantified measures (IPCC 2013). Coming back to science diplomacy and the systematization provided by the Royal Society (2010), the IPCC is a central enabler of *science in diplomacy*, facilitating the incorporation of uncertain evidence into policymaking (Ruffini 2018) and advancing precautionary action despite a lack of certainty in the available scientific data (Crawford-Brown and Crawford-Brown 2011). As a first example, this illustrates how science diplomacy contributes to climate treaties, such as the Paris Agreement, by facilitating the integration of scientific uncertainty into policymaking. On a critical note, however, the Paris Agreement is not only a demonstration of the successes of science diplomacy and the constructive approach to navigating uncertainty. In both the previous decade and the current one, the United States withdrew from the agreement under President Trump, most recently in January 2025, highlighting the fragility of gains achieved through science diplomacy.

Reviewing emerging perspectives from the past decade reaching into the early 2020s, however, a constructive understanding dominates, emphasizing positive reinforcement of the science–policy nexus through the effective handling of scientific uncertainty. This is exemplified by uncertainty’s capacity to catalyze three key dynamics that are instrumental for addressing contemporary global challenges through science diplomacy. The following sections present a literature-based conceptualization of the central functions attributed to scientific uncertainty: (I) Its capacity to facilitate national and international collaboration at the science–policy interface, (II) its potential to serve as a tipping point for maintaining trust at the nexus of policy, science, and the public, and (III) its role in prompting immediate policy action. In consideration of previous developments of the perception and navigation of scientific uncertainty, a constructive approach is adopted that nevertheless encompasses the risks and challenges associated with the functions of scientific uncertainty presented.

Scientific Uncertainty as a Catalyst for Science–Policy Cooperation and Cross-Border Partnerships

Scientific uncertainty about the impacts of climate change or technological responses to environmental threats is considered a major challenge that, at the

same time, opens a door for increased collaboration and dialogue at the science–policy interface (German Academic Exchange Service 2022; OECD 2013; Leach 2015). This marks a central chance, since an intensification of cooperation, for instance, through facilitating the translation of scientific uncertainty into applicable information for policymaking, is crucial in the face of acute threat and immediate need for climate action (Piaget 2023; Porter and Dessai 2017; European Commission 2018). To advance climate policy, the scientific community is increasingly involved as an advisory body in addressing environmental threats and crises of global relevance. Here, international scientific networks enable a deeper understanding of the inherent scientific uncertainties for the subsequent policymaking process through a variety of regional perspectives and experiences (German Academic Exchange Service 2022; Rabitz et al. 2022; Dobush et al. 2022). The greater integration of scientific knowledge into climate change policy is contingent upon the establishment of a discourse that unites international policy actors with the global scientific community to address the complex task of managing scientific uncertainties. Further, international cooperation is essential for maintaining an ongoing discourse on frameworks for working with instead of against scientific uncertainty in the pursuit of shared objectives fostering planetary health, such as the SDGs.

A key example of how scientific uncertainty has helped to build bridges between countries in the spirit of *science for diplomacy* (The Royal Society 2010) is the Central Arctic Ocean Fisheries Agreement (CAOFA), which was signed in 2018 and entered into force in 2021 (Office of the Spokesperson 2021). As the first legally binding multilateral agreement of its kind, it takes a precautionary approach to protect an area from commercial fishing before such fishing begins (Office of the Spokesperson 2021; “Agreement to prevent unregulated high seas fisheries in the central Arctic Ocean” 2018). The CAOFA was signed by Canada, China, Denmark (in respect of Greenland and the Faroe Islands), the European Union, Iceland, Japan, Norway, Russia, South Korea, and the United States and serves two main purposes: to prevent unregulated fishing in the high seas of the central Arctic Ocean and to foster joint scientific research and monitoring (Office of the Spokesperson 2021; “Agreement to prevent unregulated high seas fisheries in the central Arctic Ocean” 2018). The combination of precautionary climate action and international scientific cooperation to inform policy decisions makes the agreement particularly relevant to the case of this chapter, as “it was the lack of knowledge and conclusive data that was cited as the impetus for cooperation” (Swan 2023, 33) despite persisting geopolitical tensions (Balton 2021; Bouffard 2022; Rees and Büntgen 2024). Due to the precautionary nature of the CAOFA and prevailing uncertainties, the signatories convene biannually to assess the progress of its implementation and joint monitoring efforts, with the objective of establishing a foundation of sufficient scientific data that “can inform decision making in relation to the viability and sustainability of any potential future fishing activities in the agreement area” (Arctic Council 2021). Looking ahead, technology offers a promising avenue to address some prevailing uncertainties through “a

combination of technologies, including monitoring technologies that use big data to predict and forecast climate change and data collected by drones to manage Arctic biodiversity and ecosystems” (Kim et al. 2020). This technological integration could further support evidence-based decision-making and enhance international cooperation toward the common goal of protecting Arctic ecosystems.

From a constructive and certainly highly optimistic perspective that is not without exceptions, navigating increasing scientific uncertainty as a shared challenge could prospectively provide an entry point for discussions on underlying climate issues and threats, where differing national interests limit dialogue and common ground. What can be concluded at this point is that scientific uncertainty, while not the only factor, holds the potential to serve as a springboard for intensifying links between policy and science, as well as across international frontiers, to harness the momentum for action on climate change.

*Scientific Uncertainty as a Pillar of Trust at the Intersection of Policy,
Science, and the Public*

In a number of health and environmental crises, trust has been an affected factor, including in the fields of technological solutions and scientific policy assessments (OECD 2023a). Against the background of climate change and increasing uncertainty among the public, policymakers, and the scientific community (Curry and Webster 2011; Meah 2019), attention is turning to the relationship between scientific uncertainty and trust. Here, too, a constructive dimension has continued to surface, coupled with a recognition of the associated challenges for *science in diplomacy* (The Royal Society 2010).

At the science–policy interface, a balance is considered necessary between communicating what science knows and what it does not know. Although it is important to communicate scientific uncertainties at an early stage, especially in the field of emerging technologies, uncertainties should not dominate communication in order to avoid frustration and questioning of science in the policy arena (C. Schneider et al. 2022; OECD 2023a). While in the previous section, a closer relationship between policy and science for an intensified exchange in the face of uncertainty was recognized as a positive development, other interpretations emphasize the risks associated with the resulting “greater certainty about uncertainty” (Meah 2019, 1618) when it comes to building trust at this nexus. Science diplomats can facilitate the process of integrating uncertain evidence into climate policy by employing their understanding of its various forms, including fundamental uncertainty, deficient uncertainty, consensus uncertainty, and technical uncertainty. An awareness of consensus uncertainty on a given issue, for instance, allows them to facilitate increased dialogue and discussion at the science–policy interface, thereby providing a foundation for integrating uncertain evidence and contrary arguments into policymaking processes, rather than possibly circumventing them due to their seeming inconclusiveness (Leach 2015). This approach turns the risk of

eroding trust into an opportunity to even strengthen it through jointly navigating scientific uncertainty and managing expectations.

To maintain trust in the policy community and in the integration of scientific assessments into the navigation of existing and future global challenges (OECD 2023a), the communication of scientific uncertainty can be a potential tool at the intersection of science, policy, and society (van der Bles et al. 2019, 2020). It may, however, also lead to the rejection of information, as Schneider et al. (2022) showed using the example of COVID-19. In persuasive contexts, for example, in questions of public health behavior, the omission of uncertainties in the evaluation of scientific evidence may be used as a deliberate tool, after intensive ethical consideration, in order to not jeopardize public confidence in recommendations for action (Schneider et al. 2022). This can be successful in the short term, but may also cause a loss of trust in the long term if a policy change is actually made as a result of a previously known uncertainty (Kreps and Kriner 2020). Therefore, in a regular information context, scientific uncertainty is considered a beneficial factor when communicating with the public to maintain trust in the long term (Schneider et al. 2022; Schuster and Scheu 2023).

However, the communication of scientific uncertainty from science to policy carries the risk of creating confusion and complications (Meah 2019; Pindyck 2021) and requires an intensified dialogue to enable an effective collaboration in current times of crises. To navigate scientific uncertainty effectively, “methods and skills must be developed by key stakeholders to operate within uncertainty, to move forward with what is known and to quickly change course based on what is learned” (Bryndum-Buchholz 2024). Thus, for uncertainty to be effectively transferred from scientific discourse to policy and for trust to be fostered, clear and accessible communication is imperative to prevent the rejection, instrumentalization, or devaluation of science and its communicators (Conway and Oreskes 2012; van der Bles et al. 2019). Among the multitude of resources designed to facilitate transparent uncertainty communication at the science–policy interface is the online platform CLIMATE-ADAPT, which was developed through a collaboration of European scientists and policymakers. It provides access to a range of information, including forecasts, case studies, and web-based materials, which are tailored to support decision-making in the context of climate adaptation. By summarizing the IPCC’s frameworks for communicating and quantifying scientific uncertainty, the platform supports the integration of uncertain evidence into policymaking by clarifying the terminology and the metrics frequently used in this context, building a common ground (Climate-ADAPT and European Environment Agency n.d.; OECD 2021). Metrics such as confidence (ranging from very low to very high, based on evidence and agreement levels) and likelihood (e.g., virtually certain to exceptionally unlikely, with corresponding probabilities) allow for the clarification of uncertainty linked to scientific knowledge. An alternative means of indicating the degree of uncertainty follows a more descriptive approach. In practice, this can entail the formulation of prospective emissions

scenarios based on a range of existing assumptions, which can then be evaluated for the purpose of decision-making on climate measures (Climate-ADAPT and European Environment Agency [n.d.](#)).

In the face of a continued state of crisis due to climate change, communicating scientific uncertainty, if properly dosed and transparently conveyed, can be a useful factor in establishing and fostering a basis of trust between science, policymakers, and the public.

Scientific Uncertainty as an Impetus for Immediate Policy Response

Science diplomacy plays a central role in navigating the complexity of global climate action through leveraging disruptive technologies (Melchor et al. [2021](#); Piaget [2023](#)). This chapter has provided an overview of how scientific uncertainty can shape *science for diplomacy* and *science in diplomacy* (The Royal Society [2010](#)) by catalyzing trust and cooperation. As a result, uncertainty can complement and strengthen the bridges that *diplomacy for science* (The Royal Society [2010](#)) builds, while at the same time reinforcing the need for science-informed policy action in addressing climate change (OECD [2021](#)). In this latter process, scientific uncertainty drives immediate policy responses by (a) raising awareness of risks and emphasizing the need for precautionary measures and (b) challenging traditional approaches and catalyzing flexibility in science-policy frameworks. From these two angles, scientific uncertainty as an impetus for immediate policy responses will be addressed as a final step of this exploration of its emerging role at the intersection of science, technology, and diplomacy over the past decade and the early 2020s.

From the first angle of uncertainty as a catalyst for policy responses, public disclosure of scientific uncertainty raises awareness of climate risks and hazards of unknown magnitude that, in turn, translate into pressure for decision-makers to address it (Pindyck [2021](#); Jacobs [2014](#)). As the complexity and uncertainty of scientific predictions about climate change increase, so do the risks of severe and irreversible damage, and the urgency to create a policy infrastructure capable of mitigating potential worst-case scenarios when they occur (Lewandowsky et al. [2014a](#); Lewandowsky et al. [2014b](#); Pindyck [2021](#)). Since the potential damage from extreme warming could be so significant that it would be irresponsible to delay action, uncertainty requires immediate policy response, which Pindyck refers to as “climate insurance” (Pindyck [2021](#), 39). This is where the second angle emerges, where early action in the form of preventive measures can be stimulated by increasing scientific uncertainty about climate change and its consequences (Lewandowsky et al. [2014a](#); Pindyck [2021](#)). In policy circles, uncertainty is a key consideration for adopting a precautionary approach in order to balance safety concerns with the need to use technological innovation to address urgent environmental threats through policy (OECD [2023b](#)). The need for precaution as an effective decision-making tool is particularly emphasized in cases where the extent and likelihood of potential harm cannot be fully assessed within science, as it is the case

with GMOs in the field of environmental biotechnology (Bouchaut et al. 2022; Lukanda et al. 2023).

As a prominent case, climate tipping points illustrate how scientific uncertainty can drive policy responses by challenging existing strategies and frameworks. Because it is “quite conceivable that when tipping events do occur, they will occur in ways that we did not expect and may not fully understand” (“Global Tipping Points” 2023, 47) so-called “unknown unknowns” and a resulting lack of scientific consensus place uncertainty at the center of debates. In a Post-Normal era, where determinants such as tipping points are difficult to predict but can lead to severe non-linear impacts on the biosphere and human society, proactive responses to uncertainties are crucial. Any delay risks further irreversible damage caused by global threats such as climate change and risks long-term agency (van der Sluijs 2012; “Global Tipping Points” 2023; Wunderling et al. 2024). The uncertainty arising from the limited predictability of tipping points through science requires the corresponding policy interactions to move beyond conventional methods, while initiating the development of new and flexible modes of collective learning through an “expanded toolbox” (Barrett and Dannenberg 2012).

The twofold need for immediate action (a) despite and (b) because of uncertainty is a unique dynamic that surfaces with growing urgency at the science-policy interface in the face of risks of irreversible damage and thus presents a significant challenge. This challenge underscores the central role of science diplomats, using their understanding and awareness of scientific uncertainty to facilitate the balancing of safety concerns, the harnessing of technological innovation, and the reconciliation of national and international interests to navigate the complexities of global climate policy.

4 CONCLUSION

In conclusion, the evolving landscape of international climate policy, technological innovation, and the growing significance of integrating scientific uncertainty into decision-making processes highlights the complexity and urgency of addressing its role in the context of science diplomacy. The central viewpoint that has emerged from this chapter is that science diplomacy not only builds a bridge for the integration of uncertain scientific knowledge into policy, but that this bridge can, in turn, be reinforced by uncertainty itself. Scientific uncertainty, while not without risks, has the potential to drive collaboration within and across borders, can foster trust, and stimulate policy responses to climate change.

Over the past decades, the role of scientific uncertainty evolved from a principally challenging phenomenon with constructive features for the science-policy nexus to a central connective at the intersection of science, technology, and foreign diplomacy. This shift is aligned with van der Sluijs’ 2005 objective of situating uncertainty “at the center of the science-policy-science-society interface” (van der Sluijs 2005, 87). An understanding of scientific uncertainty

is now considered a crucial competence for policymakers, and its presence is regarded as a prerequisite for contemporary decision-making on climate change issues. Approaches that emerged in the 1990s, such as the Precautionary Principle and Post-Normal Science, have constituted a basis for the strategies that are currently applied to navigate scientific uncertainty. These frameworks have undergone a process of development and refinement, with the incorporation of an emphasis on adaptive, collaborative, and constructive approaches in response to the inherent unpredictability of climate science.

What remains evident is that science and policy function in fundamentally different ways: While science depends on uncertainty to achieve advances, policymakers seek certainty and clear answers to urgent questions around climate change mitigation (Berger and Bosetti 2020; Bradshaw and Borchers 2000). Yet this chapter demonstrated how at this delicate intersection, science diplomacy and uncertainty can interact in a way that generates positive effects for both sides by turning the unsolicited guest into a useful component of scientific knowledge that is indispensable in an era of climate change and disruptive technologies. As scientific uncertainty has become an inevitable aspect of climate policy negotiations, its ambiguity and tentativeness, once characteristics of the “uncertainty monster” (van der Sluijs 2005, 91), have been embraced as legitimate aspects of scientific knowledge. This marks a further progression in the development of a functional perspective on scientific uncertainty. What has also continued to manifest since the 1990s is the recognition that uncertainty must not act as a brake on policy action: In fact, the opposite is the case. While the argument for acting in the face of scientific uncertainty has remained constant, the perspective has been added that action should be taken not only despite, but precisely because of scientific uncertainty. Thus, as in the case of tipping points, scientific uncertainty can act as a catalyst for policy responses to climate change. It can further act as a catalyst for science–policy and cross-border cooperation as a common concern that transcends national interests and agendas, thereby strengthening *science for diplomacy* (The Royal Society 2010), as in the case of the Central Arctic Ocean Fisheries Agreement. Finally, it can act as a pillar of trust to support *science in diplomacy* (The Royal Society 2010), particularly if common ground is established on the metrics and terms used to translate uncertainty from science to policy through mediatory resources such as Climate-ADAPT and the IPCC.

However, the inherent risks associated with scientific uncertainty remain significant. At the intersection of science and policy, it can foster trust and collaboration and, if not handled effectively, erode trust and inhibit advances. This dual function—both as a facilitator of progress and as a potential risk factor—underscores its critical role for science diplomacy operating in the STI field. The capacity to raise awareness and steer dialogue in response to the duality of catalysis and risk is a challenging, yet indispensable, quality science diplomats carry to navigate scientific uncertainty with an adapted toolbox. The irreversibility of potential damage to humans and the environment from climate change, along with the resulting uncertainty among policymakers, is

increasingly being met with a rapid pace of progress toward solutions—solutions that, in turn, constantly generate new uncertainties within the scientific community as an advisory body.

This revisit of scientific uncertainty across a period from the 1990s to the early 2020s reveals its evolution from an obstacle at the science–policy nexus into a catalyst capable of facilitating and reinforcing science diplomacy for climate policy, particularly in times of technological disruption. However, future research should remain attentive to the fragility of this upward trend, as the strategic instrumentalization of science and its inherent uncertainty has moved to center stage in world politics and geopolitical rivalry, signaling a new era of science diplomacy.

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Digital Diplomacy: The Transformative Role of Technology in International Relations

Leocadia Díaz Romero 

1 THE DIGITAL NATURE OF SOCIETIES AND SCIENCE DIPLOMACY IN THE TWENTY-FIRST CENTURY

In the dawn of the twenty-first century, we find ourselves amidst a profound transformation of human society, galvanized by the swift advancement of technology and artificial intelligence (AI). This technological transformation, commonly known as the third industrial revolution, is reshaping our world in ways that were once the realm of science fiction. From the economy to healthcare, from education to our daily interactions, the digital age is fundamentally altering how we work, live, and relate to one another.

The roots of this transformation can be traced back to the 1980s, which heralded what sociologist Manuel Castells (1996) termed the “Information Age.” This era incorporates the widespread use of digital logic circuits, computers, smartphones, and digital communication technologies. The term “revolution” aptly captures the remarkable political, economic, and social consequences of this phenomenon, as well as what Vincent Mosco (2005) describes as “the myth of a new world.”

Building upon these foundations, today’s technological landscape has expanded considerably. The Internet of Things (IoT), artificial intelligence, augmented and virtual reality, machine learning, and Big Data analytics are now opening new frontiers across multiple fields. Consequently, these advancements have transformed commerce, banking, government services, political participation, and social movements.

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The traditional field of diplomacy has also embraced this digital shift, highlighting the transformative role of technology in shaping international relations and public engagement. As digital technologies have become integral to public diplomacy, new concepts have emerged to describe this integration including “digital diplomacy,” “virtual diplomacy,” “net diplomacy,” “cyber diplomacy,” “Web diplomacy,” “public diplomacy 2.0,” “tech diplomacy,” and “online diplomacy,” alluded by Bjola and Manor (2022), Holmes (2015), and Manor (2019), among other scholars.

Manor (2019) provides an all-encompassing explanation of this phenomenon, characterizing the transition to digital public diplomacy as a continuous transformation where electronic tools significantly shape the norms, values, and routine operations of diplomatic organizations. Moreover, Manor underscores that this technological paradigm goes beyond operational changes, influencing the conceptual frameworks and individual stories diplomats use to comprehend and express their role in the field. Manor’s vision encapsulates the far-reaching impact of digitalization, emphasizing its role not just in changing operational methods but in reimagining the conceptual framework of diplomacy itself.

Within this rapidly evolving digital landscape, science diplomacy has surfaced as a critical dimension of international relations, serving as a bridge between technological progress and diplomatic practice (Gluckman et al. 2017). This notion has evolved into the more comprehensive framework of science, technology, and innovation diplomacy (STI) (Araújo-Moreira et al. 2022), which recognizes the inseparable nature of these domains in addressing global challenges. The intersection of science diplomacy with digital transformation is particularly significant, as both fields share the fundamental goal of fostering international collaboration and knowledge exchange (Degelesegger-Márquez et al. 2019). Science diplomacy, which encompasses scientific cooperation between nations, science-based policymaking, and diplomatic efforts to respond to worldwide concerns, has been profoundly impacted by the digital revolution (Ruffini 2017). The rise of digital platforms and tools has not only facilitated scientific collaboration across borders but has also created new channels for science-based diplomatic initiatives, particularly in confronting global challenges such as public health crises, climate change, and technological governance (Kaltofen and Acuto 2018).

2 ONLINE PUBLIC DIPLOMACY: VIRTUAL EMBASSIES, SOCIAL MEDIA, OTHER DIGITAL PLATFORMS, AND TOOLS—IMPLICATIONS FOR SCIENCE DIPLOMACY

The landscape of international relations has been profoundly transformed by the advent and evolution of digital diplomacy over the past two decades. This revolution traces its origins to 1992, a year marked by two seminal developments that laid the foundation for a new era in diplomatic practices. During the Earth Summit in Rio de Janeiro, environmental activists broke new ground by

leveraging emails and mailing lists to orchestrate their lobbying efforts and negotiation strategies, heralding the first significant application of digital communication tools in diplomatic contexts. Concurrently, on the Mediterranean island of Malta, the Academy of Diplomatic Studies took a visionary step by establishing the pioneering Unit for Computer Applications in Diplomacy. This prescient initiative would later blossom into DiploFoundation, an institution that has, over the subsequent twenty years, played an instrumental role in shaping the digital diplomatic landscape. Through its dedicated research and comprehensive training programs, DiploFoundation has equipped thousands of diplomats with the knowledge and skills to harness the transformative power of computers and the Internet in their practice.

Email revolutionized diplomatic communication, paving the way for faster and more efficient exchanges. This transformation was further enhanced by the extensive proliferation of online platforms among foreign ministries and global institutions, greatly improving transparency and the dissemination of essential information. The integration of computers, notebooks, and Wi-Fi in conference rooms further modernized diplomatic operations, streamlining processes and making them more accessible.

In recent years, the rise of social media platforms like blogs, Facebook, and Twitter has had a transformative impact on diplomacy, allowing diplomats to engage directly with global audiences and opening up new avenues for dialogue and influence. These digital tools have not only challenged traditional diplomatic practices but also created innovative opportunities for engagement and outreach in the international arena. In parallel with these developments, science diplomacy has materialized as a vital component of digital diplomatic engagement. The intersection of scientific advancement and international relations has found new expression through digital platforms, enabling unprecedented global collaboration in research and innovation (Turekian and Gluckman 2024).

Contemporary digital diplomacy is exemplified by several key practices. Social media campaigns effectively engage global audiences on critical issues such as human rights, democracy, and cultural exchange, facilitating direct and impactful communication. Virtual embassies are integral to modern diplomacy, extending the functions of traditional embassies into the online space. Additionally, online public diplomacy further demonstrates how digital platforms can enhance a nation's global presence and influence.

The case studies that follow demonstrate how digital transformation has fundamentally reshaped diplomatic engagement, revealing successful implementations that span diverse global contexts. This evolution aligns with Diamond and McDonald's (1996) multi-track diplomacy framework, which identifies nine essential stakeholder categories: government officials, conflict resolution professionals, business leaders, private citizens, academic institutions, activists, religious organizations, funding entities, and media channels. Their model recognizes that contemporary diplomacy functions through an intricate web of relationships that transcends conventional diplomatic

protocols, creating a rich ecosystem of international engagement that harnesses scientific collaboration as a powerful diplomatic tool to address shared global challenges.

Virtual Embassies

In the evolving landscape of international diplomacy, virtual embassies constitute an innovative approach to diplomatic representation. These digital missions offer a unique solution for nations seeking to establish a diplomatic presence without maintaining a physical embassy in the host country. Proponents argue that virtual embassies can function effectively with an ambassador operating from their home nation, leveraging electronic communication to fulfill diplomatic duties.

The concept of virtual embassies is underpinned by two primary rationales. Firstly, they offer significant cost savings for the sending state, eliminating the need for expensive physical infrastructure and staffing abroad. Secondly, they provide a means of diplomatic representation in countries where establishing a traditional embassy may be impractical or impossible. They administer essential consular services, such as visa processing, passport renewals, and citizen assistance, particularly benefiting those in regions without a physical embassy presence. As hubs of public diplomacy, these digital diplomatic platforms showcase a nation's heritage, principles, and governmental strategies to an international community through Web sites, social media, and online events. In times of crisis, they offer real-time updates, guidance, and support, enabling swift communication and coordination with citizens and other governments. Additionally, they maintain strong ties with expatriates and diaspora communities, offering resources and cultural links to keep them connected to their home country.

Sweden's "Second House of Sweden" (2007–2012)

Sweden led the way in digital diplomacy by launching a groundbreaking virtual embassy on the innovative platform SecondLife.com. Referred to as the "Second House of Sweden," this digital embassy was designed to engage directly with users in the virtual world, giving Sweden a unique avenue to connect with a global audience while promoting its artistic and cultural heritage. Initially, the embassy operated at full capacity, but over time, its digital staff presence gradually declined, transforming the space into a lively cultural hub. The embassy offered a variety of interactive experiences, such as lectures on Swedish culture, live musical performances, and celebrations of Sweden's national day, all intended to provide visitors with immersive cultural encounters rather than merely sharing information (Pamment 2013).

The virtual embassy closed its doors in 2012, largely due to the technological limitations of the time, which prevented the creation of a fully functional and engaging online diplomatic presence. Despite facing challenges in attracting substantial audiences, the embassy was recognized as a pioneering experiment that ultimately outpaced the capabilities of early virtual technology.

Pamment argues that it may have anticipated the development of dialogic diplomacy practices later facilitated by social media platforms.

Maldives' Virtual Embassy (2007)

Inspired by Sweden's digital diplomacy experiment, the Maldives established its own virtual embassy on SecondLife.com. This bold initiative aimed to forge new pathways in international relations, offering a particularly promising avenue for smaller nations constrained by limited resources for traditional diplomatic endeavors. However, the embassy's potential was ultimately curtailed by the technological limitations of the platform, hampering its growth and effectiveness in the digital diplomatic sphere.

United States' Virtual Representation (2003–2011)

The United States charted a unique course in virtual diplomacy, leveraging existing governmental Web platforms to create a network of approximately 40 virtual representations. In a departure from the approaches of Sweden and the Maldives, the United States explicitly positioned these digital entities not as official embassies but as bridges for cultural exchange. Despite this innovative approach, these virtual initiatives failed to gain traction and were eventually discontinued due to lackluster engagement and popularity, highlighting the challenges of sustaining interest in digital diplomatic efforts.

It is convenient to highlight some contemporary examples of virtual embassies that remain active today. *The US Virtual Embassy to Iran* (2011–today) serves as the main official channel through which Iranian citizens can access direct information from American authorities regarding US policies, culture, and fundamental principles. This digital initiative was established by Washington to offer details about studying in America, visa applications, and broader US foreign policy positions, including those concerning Iran and international affairs. While not an actual embassy or official diplomatic presence recognized by Tehran, and without the status of a traditional diplomatic facility, this online platform aims to foster connections between Americans and Iranians when direct diplomatic relations are not possible. To expand its digital outreach, the U.S. government maintains a comprehensive social media presence through its USABehFarsi channels across multiple platforms, encompassing Facebook, Twitter, YouTube, Instagram, and Telegram. Throughout its inaugural year of operation, the primary online platform representing the United States' digital diplomatic presence for Iran attracted approximately two million visits from Iranian users (The Times of India [2012](#)).

The Estonian Data Embassy (2018–Today)

Estonia's inauguration of the earliest known Data Embassy in Betzdorf, Luxembourg, in 2018 marked a revolutionary advancement in digital sovereignty. This pioneering initiative transcends conventional data backup systems by creating a comprehensive digital mirror of the nation's critical infrastructure, including vital government databases, registries, and information systems.

Operating from a sovereign data center on foreign soil, the facility enjoys unprecedented diplomatic privileges and immunities typically reserved for traditional embassies, effectively extending these protections to the digital realm.

For Estonia, the Data Embassy represents more than mere technological innovation—it embodies a sophisticated defense mechanism against modern threats to state continuity. This visionary approach to preserving governmental functionality has particular resonance for nations facing existential challenges, whether through contested diplomatic recognition, territorial sovereignty disputes, or environmental vulnerabilities. The concept of extraterritorial data preservation, coupled with the capability to maintain dormant state operations, emerges as a powerful strategic response to an increasingly volatile global landscape.

Estonia's Data Embassy initiative exemplifies a forward-thinking approach, representing both a practical governmental solution and a strategic framework for anticipating and mitigating potential catastrophes (Anderson 2010). The implications extend beyond mere data protection, intersecting with broader national security strategies and emergency management protocols (O'Grady 2018).

The emergence of Digital Sovereign Repositories signals a broader paradigm shift in state governance and survival strategies. As the global environment becomes more uncertain, cloud-based governmental operations and remote data preservation will likely gain prominence, particularly among vulnerable nations. These repositories represent novel political constructs that challenge conventional notions of statehood and sovereignty (Pistor 2020). While the concept of a fully virtual nation-state remains beyond current international legal frameworks, the principle of digital dormancy opens new horizons in modern statecraft—suggesting pathways not only for survival but for the fundamental reinvention of governmental functions in the digital age.

This unprecedented form of diplomatic cooperation, where one nation safeguards another's digital infrastructure, may inspire other countries to establish similar arrangements. As this new phase of diplomatic relations centered around digital information protection evolves, scholars suggest the broader application of the Vienna Convention to accommodate these contemporary digital diplomatic activities (Robinson et al. 2019). The Data Embassy concept thus offers a blueprint for national resilience in an increasingly digitalized world while simultaneously pioneering new forms of international cooperation.

The Social Media Arena

Twiplomacy, Snapchat, WhatsApp Diplomacy

Twiplomacy

Barack Obama paved the way for political leaders on social media when he created his Twitter account in 2007, marking a historic first for heads of state. His

early adoption of the platform influenced countless other government leaders and representatives to establish their own social media presence (Margianta 2014). The landscape of diplomatic communication underwent a transformative realignment in 2009 when the White House boldly entered Twitter, building upon the United Nations' groundbreaking digital strategy. A particularly momentous milestone happened when Arturo Sarukhan, Mexico's ambassador to the United States, shattered traditional diplomatic protocols in November 2009 by becoming the first foreign envoy in Washington, DC to harness Twitter potential for official governmental discourse.

Pioneering digital interactions continued to evolve rapidly. In 2010, Helen Clark, former head of the UN Development Program, emerged as a trailblazer among senior UN officials by embracing social media's communicative power. The Israeli Embassy further expanded the horizons of public diplomacy in 2013, strategically leveraging digital platforms to present an official record of President Obama's diplomatic mission to Israel, demonstrating the nuanced capabilities of real-time global communication.

The true revolutionary potential of social media platforms crystallized dramatically in 2014 through the #BringBackOurGirls campaign. This powerful global movement, sparked by the heartbreaking abduction of Nigerian schoolgirls, transcended traditional media boundaries. With high-profile endorsements, including a passionate intervention by former First Lady Michelle Obama, the campaign illuminated social media's unprecedented capacity to instantaneously mobilize international solidarity, transform public consciousness, and apply pressure on global humanitarian issues.

These pivotal moments represented more than technological innovations; they signaled a fundamental reimagining of diplomatic communication, where digital platforms became critical instruments of global dialogue, awareness, and collective action.

Social media have become a transformative mechanism for India's strategic global communication and soft power projection. Through sophisticated utilization of prominent networks like Twitter (now X), Facebook, and Instagram, the nation has crafted a nuanced approach to international engagement that transcends traditional diplomatic channels. The year 2010 witnessed the Indian Ministry of External Affairs' digital debut, as the ministry published its first tweet, effectively bridging traditional diplomatic practices with the emerging digital communication landscape. Since then, the Indian Ministry of External Affairs maintains highly popular social media accounts on X (formerly Twitter) that provide comprehensive updates on diplomatic activities. These handles, including @meaMADAD and @IndianDiplomacy, offer real-time information about international visitors, diplomatic discussions, official statements, ambassador appointments, and other significant foreign policy communications, effectively keeping the public informed about India's global interactions and promoting meaningful connections with the expansive global Indian diaspora.

Snapchat

In a remarkable digital diplomacy breakthrough, governmental and humanitarian organizations transformed communication paradigms by embracing Snapchat as a strategic platform. The United Kingdom's foreign office pioneered this approach, creating an innovative channel that merged professional insights with accessible, visually dynamic storytelling. The United Nations quickly followed suit, legitimizing Snapchat as a credible medium for global dialogue.

The pinnacle of this digital transformation emerged in 2015 through a powerful collaboration between UNICEF and Snapchat. Their groundbreaking awareness campaign transcended traditional media limitations, casting a stark spotlight on the humanitarian crisis in Nigeria. By leveraging multimedia storytelling, they exposed the devastating impact of Boko Haram's terrorism on children, drawing unprecedented global attention to a complex humanitarian challenge (Rashica 2018). This strategic digital initiative represented a profound reimagining of how institutional narratives could be constructed and shared in an increasingly interconnected world. By penetrating digital consciousness and engaging younger generations, these organizations demonstrated an extraordinary capacity to transform global communication and raise awareness about critical, often-overlooked social issues.

WhatsApp Diplomacy

WhatsApp has revolutionized global communication, becoming a transformative platform that has reshaped diplomatic and negotiation strategies. Dubbed "WhatsApp diplomacy" by journalists, the messaging application has become one of the world's most rapid digital communication networks, enabling instantaneous, direct interactions across international boundaries. Its unprecedented speed and accessibility have fundamentally altered how professionals, policymakers, and diplomats exchange information and conduct negotiations (Singh 2018).

Social Media Diplomacy During Crisis or Conflict

The digital revolution has transformed diplomatic communication, enabling citizens to seek immediate assistance through online social networks. What previously required days of offline communication and complex bureaucratic processes can now be accomplished with a single tweet. Expatriates and travelers can rapidly reach their embassy representatives, dramatically reducing response times and increasing the accessibility of consular support. This represents a significant evolution in how international assistance is requested and delivered, leveraging real-time digital communication to bridge geographical and administrative barriers.

For instance, during the 2011 Libyan civil conflict, India effectively used Twitter (now X) to evacuate nearly 18,000 citizens. The Ministry of External Affairs effectively harnessed social media hashtags to enhance rescue and assistance efforts during critical events like the riots in Israel and Sudan,

demonstrating how these digital tools can swiftly mobilize support (Mohilay 2023). Later in 2023, during the Sudan conflict, India launched #OperationKaveri, successfully evacuating nearly 2500 Indian nationals from the war-torn region. Similarly, during the Israel-Hamas crisis, the Ministry of External Affairs initiated #OperationAjay, which trended on social media and resulted in the rescue of over 1300 people, demonstrating India's commitment to protecting its citizens during international emergencies.

As a non-profit organization, United Help Ukraine (UHU) strives to deliver essential aid to Ukrainians, supporting their fight for survival, territorial integrity, and long-term prosperity. The organization ensures donations achieve their greatest potential by delivering vital supplies, healthcare support, and mental health services to war-affected individuals. Additionally, UHU works to maintain global attention on Ukraine's struggle while championing its continued existence as a sovereign democratic state. UHU maintains robust engagement on major social networks, from Facebook and X to Instagram and LinkedIn, alongside its main Web site to help accomplish these objectives.

Social Media Diplomacy Amid Global Challenges

Misinformation

The digital revolution has fundamentally transformed information warfare through sophisticated platforms that amplify the reach and impact of hostile actors. These advances have created an ecosystem where disinformation spreads with unprecedented velocity and precision, reaching millions within hours while dynamically evolving to evade detection systems. The implications extend far beyond traditional security concerns, reshaping how societies consume and process information.

Recognizing this critical threat, the European Union and its member states have elevated the battle against information manipulation to the forefront of their strategic agenda. Their multifaceted response integrates three core pillars: strengthening digital resilience across communities, fostering robust cross-border collaboration, and developing cutting-edge countermeasures to safeguard both public discourse and democratic institutions.

The EU's commitment to this fight extends to its own digital presence and regulatory framework. A prime example is the European Commission's strategic use of social networking sites to combat misinformation. Through these channels, the Commission has actively promoted groundbreaking legislation like the Digital Services Act (DSA)—whose primary objective is to combat unlawful content, reduce damaging behaviors in digital spaces, and curtail the dissemination of false information—while also demonstrating its enforcement resolve by publicly announcing in December 2024 formal proceedings against platforms like TikTok for suspected DSA violations. This dual approach of regulation and public engagement illustrates the EU's determination to forge a more transparent and accountable digital information space. The European Commission issued proposed guidelines on 18 July 2025 to clarify how the AI

Act's main provisions apply to General Purpose AI (GPAI) systems, reinforcing the EU's commitment to regulating advanced technologies with transparency and precision (European Commission 2025).

The intersection of science diplomacy and the battle against misinformation has emerged as a crucial frontier in the EU's digital strategy. Drawing on established networks of scientific collaboration, EU member states have mobilized interdisciplinary expertise to develop evidence-based approaches to combat disinformation. Legal scholars, computer scientists, and social scientists across European research institutions have collaborated through digital platforms to draft comprehensive regulatory frameworks like the Digital Services Act. These collaborative efforts exemplify how scientific diplomacy networks can be deployed to address emerging digital threats. For instance, the European Digital Media Observatory (EDMO) has created a cross-border network of fact-checkers, academic researchers, and media literacy experts who work together to detect and analyze disinformation campaigns while also developing AI-powered tools for automated detection of false information. The spread of deepfakes and AI-generated propaganda during international conflicts has prompted diplomatic institutions to adopt new digital verification protocols. These include real-time fact-checking tools and AI-detection systems designed to safeguard public trust and prevent escalation from disinformation campaigns (Turekian and Gluckman 2024). This fusion of scientific expertise with diplomatic initiatives has strengthened the EU's capacity to respond to the evolving challenges of the digital information space, demonstrating how science diplomacy can enhance regulatory effectiveness and public resilience against misinformation.

Natural Disasters

In today's digital age, social media and Geographic Information Systems (GIS) have become cornerstone technologies in disaster management, particularly as natural disasters increase globally. This evolution is especially relevant for Japan, where seasonal weather patterns pose significant threats to communities and infrastructure.

The transformative moment came during the 2011 Great East Japan Earthquake, when damaged communication networks led to social media becoming an unofficial emergency broadcast system. Citizens armed with smartphones became frontline reporters, documenting disaster zones through multimedia posts before traditional media could arrive. This grassroots response catalyzed Japan's integration of social media into its L-Alert disaster communication system, strengthening its emergency response capabilities. The Japanese government formalized this approach in 2017 when the Cabinet Secretariat published guidelines for leveraging social media during disasters, providing a framework for local authorities. The 2018 Western Japan floods further demonstrated the power of integrated social media and Geographic Information Systems (GIS) in crisis response. This foundation proved crucial during 2019's Typhoon Hagibis, where Nagano Prefecture's innovative use of

Twitter—including the hashtag #TyphoonHagibisDamageinNagano—facilitated 50 successful rescues (Yamamoto 2020). Building on this success, Koshigaya City pioneered standardized hashtag protocols in 2020.

The 2020 Southern Kyushu floods highlighted the stark contrast in emergency response strategies between prefectures. Oita Prefecture's dedicated social media team successfully coordinated ten rescues through Twitter, while Kumamoto Prefecture's reliance on traditional communication channels coincided with severe casualties and damage in the Kuma River region, particularly during widespread flooding.

To serve the international community and US citizens, the US diplomatic mission in Japan maintains comprehensive digital outreach through its Embassy and Consulates. Their social media presence, centered on the @ACSTOKYO handle across platforms, provides real-time emergency updates and significant information, complementing their official Web site's detailed resources. This multi-channel approach ensures reliable communication during crises.

Japan's response to natural disasters has been significantly enhanced through international scientific collaboration and digital diplomacy. Following the 2011 Great East Japan Earthquake, Japanese scientists established robust partnerships with international research institutions, leading to advanced early warning systems and improved disaster prediction models. Through platforms like the Pacific Tsunami Warning System (PTWS), Japanese scientists collaborate in real time with counterparts across the Pacific Rim, sharing seismic data and improving tsunami forecasting accuracy. The International Research Institute of Disaster Science–Tohoku University exemplifies this approach, hosting researchers from over 30 countries who work together to develop innovative disaster resilience technologies. These scientific partnerships extend to space-based monitoring, with Japan's JAXA working closely with NASA and ESA to utilize satellite data for tracking typhoons and flooding patterns. This international scientific cooperation has not only strengthened Japan's disaster preparedness but has also contributed to global understanding of disaster management, as demonstrated during the 2018 Western Japan floods when international teams of hydrologists and meteorologists collaborated through digital platforms to provide critical flood monitoring and prediction support.

Climate Change

The global climate action movement known as #FridaysForFuture emerged in August 2018 when Greta Thunberg, at age 15, along with fellow young protesters, staged a 3-week demonstration outside Sweden's parliament building during school hours. Their protest against climate inaction gained widespread attention after Thunberg shared their activities on social platforms. The movement's digital strategy revolves around major social networks, where they coordinate strike events, showcase protest documentation, spread environmental awareness, and build community engagement. Through targeted hashtag campaigns like #FridaysForFuture and #ClimateStrike, the organization creates momentum by combining firsthand accounts, informative resources, and direct

appeals for participation. Their social media presence serves as a powerful tool to expand their reach and inspire others to join their environmental advocacy efforts.

The global response to climate change has been fundamentally shaped by unprecedented international scientific cooperation, extending far beyond grassroots movements, and technology. The Intergovernmental Panel on Climate Change (IPCC) constitutes one of the most ambitious scientific diplomatic initiatives in history, bringing together thousands of researchers from 195 countries to assess climate science, impacts, and mitigation strategies. This scientific collaboration has been instrumental in major diplomatic achievements like the Paris Agreement, where evidence-based policy recommendations informed international negotiations. Digital platforms have revolutionized how climate scientists share and analyze data, with initiatives like the World Climate Research Programme coordinating global research efforts through virtual laboratories and shared databases. Major research institutions, including NASA, ESA, and various national meteorological agencies, maintain sophisticated networks for sharing satellite data and climate models in real time. The Global Climate Observing System exemplifies this international scientific cooperation, connecting over 150 countries in monitoring essential climate variables. These collaborative efforts have been crucial in developing standardized methodologies for measuring greenhouse gas emissions, creating unified climate projection models, and establishing science-based targets for emissions reduction that inform both policy decisions and corporate climate strategies.

Increasingly, digital diplomacy tools have become essential in global fora. During COP29 (2024), interactive climate dashboards, VR simulations, and hybrid meeting platforms were used to facilitate remote participation and data transparency, reinforcing the role of technology in inclusive environmental negotiations (United Nations Framework Convention on Climate Change 2024).

Other Digital Platforms and Tools and Science Diplomacy

India has strategically leveraged digital platforms to cultivate and amplify its global economic and scientific diplomacy, utilizing innovative technological initiatives to showcase its developmental potential and forge international partnerships. The nation's scientific expertise has been particularly evident in its space program collaboration through the Indian Space Research Organisation, which maintains digital platforms for sharing satellite data and research findings with international partners. Through these scientific networks, India has strengthened its position in global research communities while addressing shared challenges like climate monitoring and disaster management.

Prominent among these transformative initiatives are flagship programs. *Digital India* aspires to create a societal ecosystem enhanced by technology while also facilitating international scientific collaboration through virtual research laboratories and data-sharing platforms. Complementing this are

specialized platforms like the *India Development Foundation*, the *Indian Technical and Economic Cooperation* program, and the interconnected *e-Vidya Bharati* and *e-Arogya Bharati networks*. The integrated approach illuminates India's sophisticated vision of digital technologies as critical instruments for constructing international relationships, driving economic collaboration, and enabling comprehensive technological knowledge transfer (Preethi Amaresh 2020). This is exemplified by initiatives like the India-EU Science & Technology Cooperation portal, which connects researchers across continents and facilitates joint research projects in areas ranging from biotechnology to artificial intelligence.

The United Nations Sustainable Development Goals (SDG) Action Campaign launched a pioneering virtual reality (VR) initiative in 2015 to foster empathy and understanding of global challenges. This immersive technology allows decision-makers and citizens worldwide to experience firsthand the daily struggles of vulnerable populations through 360-degree interactive storytelling.

The project leverages advanced VR headsets to create powerful, three-dimensional experiences that transport viewers directly into critical situations, from conflict zones to areas affected by climate change, health crises, and natural disasters. By providing this close perspective, the initiative aims to inspire concrete action and policy changes that benefit those most at risk of being overlooked in global development.

While initially focused on influencing key decision-makers, the campaign has expanded its scope through partnerships to develop advocacy platforms and awareness campaigns. The project continues to document pressing global issues like migration, pollution, and humanitarian crises, seeking collaborators who share the vision of creating meaningful social change through technological innovation.

All in all, the *UN Virtual Reality Series* can foster scientific innovation and diplomatic initiatives to address global challenges. Beyond its storytelling capability, the platform has the potential to serve as a hub for scientific data visualization, allowing researchers and policymakers to experience complex scientific phenomena in immersive environments. Therefore, climate scientists could use the platform to demonstrate atmospheric changes, while medical researchers employ it to illustrate global health challenges. The initiative can foster partnerships with leading research institutions worldwide, creating a network for sharing scientific insights through virtual reality.

At this respect, it is convenient to highlight the UN Climate Visualization Project, which has used virtual reality, augmented reality, and artificial intelligence to visualize climate change impacts on Mauritius and surrounding island coastlines. These immersive visualizations translate complex data into intuitive, accessible formats supporting education and emergency preparedness in line with UN priority areas. The project is actively building relationships with both local and international institutions to enhance its capabilities. Key partnerships include the Mauritius School of Architecture, Mauritius Research and

Innovation Council, and National Computer Board, providing access to aerial photogrammetry equipment, laser cutting technology, and 3D printing resources.

The *Digital Public Square* initiative emerged from the Munk School at the University of Toronto in 2013, initially concentrating on internet freedom and governmental transparency. Through subsequent years, the team broadened its focus to encompass digital campaigns championing gender equality, interactive platforms promoting human rights, and global digital literacy programs. The project's evolution led to its establishment as an independent non-profit organization in 2016, with aims to expand its reach and create sustainable technological solutions for lasting social impact. Since then, the Digital Public Square has extended its influence across multiple continents, touching the lives of millions through innovative digital initiatives spanning from the Americas to Asia, Europe to Africa, and throughout the Middle East. The endeavor could lead to cross-border scientific partnerships, hosting virtual conferences where researchers from different continents can share findings and methodologies in real time. There are as well possibilities to develop sophisticated tools for scientific data visualization and analysis, making complex research accessible to broader audiences while maintaining scientific rigor. On the whole, the Digital Public Square offers prospects to create a global network of scientific expertise, enabling researchers and institutions to collaborate seamlessly.

Regarding science diplomacy, digital platforms have become essential tools for facilitating global research partnerships, sharing scientific data, and coordinating responses to global challenges that require scientific expertise. Major scientific institutions have implemented digital platforms to enhance international cooperation. The European Organization for Nuclear Research (CERN) digital infrastructure extends beyond social media to include sophisticated online platforms that enable particle physicists worldwide to collaborate seamlessly. Similarly, the European Space Agency (ESA) and NASA maintain robust digital ecosystems that facilitate international space cooperation through virtual mission control centers and data-sharing platforms.

3 PANDEMIC DIPLOMACY: INTERSECTIONS OF DIGITAL TOOLS AND SCIENCE DIPLOMACY

The COVID-19 pandemic stands as a prime illustration of the integration of social media, digital platforms, and advanced tools within the realm of diplomacy. When COVID-19 swept across the globe in early 2020, it didn't just disrupt daily life—it revolutionized the centuries-old practice of international diplomacy. A profession built on personal connections and nuanced face-to-face interactions suddenly found itself thrust into the digital realm, forcing world leaders to navigate complex international relations through the limiting frame of computer screens.

This pandemic disruption simultaneously catalyzed an unprecedented mobilization of global scientific collaboration. Within weeks of the first reported

cases, researchers across continents were sharing genomic data, clinical observations, and potential treatment protocols through digital channels, creating a new paradigm of real-time scientific diplomacy that transcended traditional institutional boundaries. This scientific cooperation became as crucial to pandemic response as traditional diplomatic relations, with researchers and public health officials engaging in direct cross-border communication at a pace and scale never before witnessed.

The transformation proved both swift and comprehensive. Conventional diplomatic protocols gave way to virtual encounters. Social media platforms, particularly Twitter, emerged from the periphery to become central channels of diplomatic communication. Leaders who had once viewed digital platforms with skepticism now embraced them wholeheartedly, using these tools to share critical public health guidance and rally citizens around initiatives like #StayHome. Even the Vatican, an institution steeped in tradition, adapted to this new reality as Pope Francis turned to Skype to maintain his global ministry.

The scope of this digital transformation was remarkable. By 2020, 189 of 193 UN member states maintained active Twitter presences, commanding an audience of over 620 million followers, with the only exception of Laos, North Korea, Sao Tome and Principe, and Turkmenistan that remained outside this digital diplomatic sphere.

Major diplomatic gatherings underwent unprecedented changes. Both G7 and G20 summits shifted to virtual formats, with Saudi Arabia hosting the latter in a striking display of technological adaptation. Estonia emerged as a digital diplomatic pioneer during its UN Security Council presidency, orchestrating a virtual gathering of 80 nations to commemorate the 75th anniversary of the conclusion of World War II with #LessonsForPeace. This new era even generated its own vocabulary, with Israeli diplomat Joshua Brook coining the term “Zoomplomacy” to describe the phenomenon of leaders sharing screenshots of their virtual summits.

In parallel, the scientific community was pioneering its own forms of digital collaboration that would soon influence diplomatic practices. International research consortia established virtual laboratories where scientists could collectively analyze viral genomes and test potential vaccines regardless of geographical location. Platforms like the Global Initiative on Sharing All Influenza Data (GISAID) became diplomatic spaces in themselves, where countries shared crucial viral sequence data under collaborative frameworks that balanced national interests with global public health needs. These scientific collaborations often preceded and informed formal diplomatic agreements on pandemic response, creating a new prototype for science-led diplomacy in crisis situations.

The pandemic also transformed how leaders engaged with the media and their citizens. Peter Stano of the European Union’s External Action Service addressed journalists from a vacant press room, their faces visible only through video screens. Jamaica’s Prime Minister Andrew Holness embraced Zoom for media interactions, while European leaders Angela Merkel and Emmanuel

Macron conducted joint press conferences via video links between Berlin and Paris. The UK government pioneered a more interactive approach, welcoming public questions through social media for their daily coronavirus briefings, while Israel's Foreign Ministry hosted dynamic "Ask Us Anything" sessions on Twitter during lockdown.

Scientific briefings themselves evolved into significant diplomatic events during this period. Chief medical officers and leading researchers frequently joined government officials in press conferences, elevating scientific communication to the diplomatic stage. These briefings represented a new hybrid form of science diplomacy, where scientific consensus was publicly negotiated alongside policy decisions. The presence of scientific authorities alongside political leaders in these communications signaled to global audiences the importance of science-based perspectives, while differences in scientific messaging between countries sometimes revealed underlying diplomatic tensions or divergent national priorities.

Perhaps the most dramatic demonstration of this new digital diplomacy came through the massive repatriation efforts. The European Union alone coordinated the return of over 590,000 citizens, while foreign ministries worldwide documented these unprecedented operations across social media. The surge in citizen communication overwhelmed traditional channels—Germany's Foreign Ministry saw a fivefold increase in social media engagement, handling 38,000 messages during peak repatriation efforts. Switzerland's diplomatic corps managed more than 10,000 calls and 18,000 emails while maintaining constant social media communication. Nations like Belgium created lasting records of these historic missions through compelling video documentaries shared on Twitter.

These repatriation operations represented a complex integration of diplomatic action with scientific protocols. International health agencies and scientific bodies established evidence-based guidelines for safe travel and quarantine procedures that diplomatic missions had to incorporate into their repatriation plans. This coordination demonstrated how scientific consensus directly shaped diplomatic operations, with foreign ministries consulting with epidemiologists and public health experts to determine when and how citizens could be safely returned home. The digitization of these processes allowed for rapid updates to protocols as scientific understanding of the virus evolved, creating an adaptive model of science-informed diplomatic practice.

As the world adapted to post-pandemic realities, major diplomatic gatherings like the UN General Assembly and the World Economic Forum adopted hybrid formats, combining limited in-person attendance with substantial online participation. While masked diplomats cautiously resumed some face-to-face meetings, the efficiency and reach of digital diplomacy ensured its continued prominence in world politics. Some scholars have defined this emerging diplomatic paradigm as "hybrid diplomacy," characterized by the deliberate alternation of in-person and digital interactions that mutually reinforce, supplement, and strengthen one another's effectiveness (Bjola and Manor 2022).

Digital platforms originally developed for scientific collaboration during the pandemic began influencing broader diplomatic information exchange. The transparency and verification mechanisms built into scientific data-sharing platforms like the Global Initiative on Sharing All Influenza Data (GISAID) offered models for diplomatic communications that required both security and accessibility. Many foreign ministries adopted similar approaches for sharing critical information during subsequent crises, implementing protocols first developed by scientific communities for pandemic response. This cross-pollination between scientific and diplomatic digital practices represented one of the pandemic's most significant and lasting institutional innovations.

This profound change sparked intense debate about its long-term implications. Some diplomats, including former UK Ambassador Tom Fletcher, expressed concern about “national distancing”—the risk that virtual barriers might reinforce political ones. Others saw opportunity in the personal connection of video calls and the democratizing effect of digital platforms, which allow diplomatic messages to reach far beyond traditional circles.

Though the pandemic accelerated this digital transformation, its lasting impact on international diplomacy has fundamentally altered how nations navigate their global relationships. Beyond pandemic unprecedented cooperation and scientific discovery, facilitated by real-time data sharing and virtual research partnerships (Lee and Haupt 2020), the digital transformation of science diplomacy not only advances scientific knowledge but also strengthens international relations through shared research objectives and collaborative problem-solving.

4 FINAL REMARKS

The digital transformation marks one of the most significant shifts in global affairs since the advent of modern diplomacy. This comprehensive analysis reveals several key conclusions about the evolving landscape of digital diplomacy and scientific cooperation in global affairs.

First, the evolution from the early experiments with virtual embassies to the sophisticated contemporary digital platforms demonstrates both the potential and limitations of technological innovation in diplomatic practice.

Second, the rise of virtual embassies and digital diplomatic platforms has created new opportunities for nations with limited resources to establish and maintain international presence. Estonia's pioneering Data Embassy initiative, in particular, illustrates how digital innovation can enhance national sovereignty and security.

Third, social media has arisen as a critical tool in modern diplomacy, fundamentally altering how nations engage with foreign publics and respond to international crises. Platforms like Twitter, WhatsApp, and Snapchat have not only accelerated diplomatic communication but have also democratized it, allowing for unprecedented levels of public engagement in international affairs. The success of digital initiatives during crises—from natural disasters to the

COVID-19 pandemic—underscores the vital role these platforms now play in diplomatic operations.

Fourth, the COVID-19 pandemic served as a catalyst for digital diplomacy, forcing rapid adaptation and innovation in diplomatic practices. The widespread adoption of virtual platforms for high-level diplomatic meetings, international negotiations, and public diplomacy initiatives during this period has permanently altered the diplomatic landscape. While face-to-face diplomacy remains valuable, digital tools have become indispensable components of modern diplomatic practice.

Fifth, the evolution of digital diplomacy has been particularly transformative in the realm of science diplomacy (Montgomery and Colglazier 2022). Digital platforms have become indispensable tools for international scientific collaboration, enabling real-time data sharing, virtual laboratories, and global research partnerships. This digital transformation has not only enhanced the efficiency of scientific cooperation but has also democratized access to scientific knowledge and expertise. A study published by the World Economic Forum during the COVID-19 crisis made emphasis on the need to cultivate a fresh cadre of leadership capable of connecting scientific and technological innovation with diplomatic practice to effectively tackle worldwide problems (World Economic Forum 2021).

Looking toward the future, the diplomatic landscape stands at the threshold of revolutionary transformation. Emergent technologies, especially artificial intelligence, data analytics, augmented reality, and distributed ledger technology, are poised to fundamentally reshape the field. These innovations promise to create new opportunities for scientific cooperation while raising important questions about technological governance and digital sovereignty. The future of science diplomacy will increasingly depend on nations' ability to navigate these digital frontiers while maintaining trust and transparency in international scientific partnerships (Gual Soler 2020). In recent years, several foreign ministries have begun integrating generative AI tools into their operations, using them to draft policy briefs, translate diplomatic content, and analyze social media trends. This shift highlights the growing importance of AI literacy in modern diplomatic training and communication (Montgomery and Colglazier 2022).

The digital diplomatic environment demands continuous professional development. Diplomats must commit to ongoing digital literacy training, adapting swiftly to emerging technologies and innovative communication strategies. Similarly, despite growing interest from young scientists and diplomats, education in science diplomacy remains largely extracurricular and fragmented. Therefore, establishing fundamental cross-cutting concepts is essential to develop and consolidate comprehensive university curricula to serve advanced undergraduate and graduate students from diverse backgrounds while being adaptable across various academic programs and disciplines (Mauduit and Gual Soler 2020). In response to the growing need for professional training, graduate-level certificates in digital and science diplomacy were launched and

are currently being offered by the Institute for the Study of Diplomacy (Georgetown University School of Foreign Service 2025), the University of Oxford Diplomatic Studies Programme (University of Oxford, Department of Politics and International Relations 2025), the United Nations Institute for Training and Research, the DiploFoundation, and the United Nations University—Institute on Comparative Regional Integration Studies—among others. These programs reflect the increasing institutionalization of science diplomacy education.

Several critical areas require attention and further research: the development of secure regulations that balance technological innovation with diplomatic tradition, the preservation of authentic human relationships amid growing artificial intelligence integration, and the creation of equitable governance systems ensuring all nations can participate meaningfully in digital and scientific diplomacy, as well as the adaptation of international legal frameworks to address sovereignty in increasingly borderless digital and scientific exchanges.

The future of diplomacy will likely be characterized by a sophisticated hybrid approach (Aggestam and Duncombe 2023) that leverages cutting-edge technology while preserving the irreplaceable human element in international relations, particularly in domains where scientific and technological cooperation forms the foundation of diplomatic engagement. This evolution in diplomatic practice promises increased transparency in worldwide affairs, democratizing access to information and encouraging greater governmental accountability (Holmes 2015).

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PART II

Actors, Intermediaries, and Interface
Institutions



The New Cadre of Technology Envoys as Diplomats: Organizational Sense or Tradition?

George R. B. Salter 

Order, interruption, recovery. That is sensemaking in a nutshell. (Weick 2006, 1731)

I INTRODUCTION

In this chapter, we consider the challenges Ministries of Foreign Affairs (MFAs) face in attempting to create a new kind of professional, the “tech diplomat,” capable of making sense of and affecting the complex and globalized dynamics of technological change. While dedicated professionals are intuitively necessary to take forward foreign policy ambitions for science and technology (S&T), professionalizing and institutionalizing this mode of diplomacy may not be so straightforward. In virtue of spanning organizational boundaries between the state and its foreign policy bureaucracy, the private sector, and scientific communities, and operating in a context of often rapid technological innovation, tech diplomats will face challenges in interpreting their environments and enacting meaningful diplomatic initiatives. It may seem like an organizational success to have these professionals at work, but this move should not mask the wider complexities of negotiating the evolving dynamics of S&T.

We draw on the organizational theorist Karl Weick’s notion of “sensemaking,” broadly construed as the practice of “structuring the unknown” to take action, in order to conceptualize and unpack the unique contours of these issues (Weick 1995). The chapter is written from a deliberately state-centric

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J. Lüder, M. Wählich (eds.), *The Palgrave Handbook of Science Diplomacy*,
https://doi.org/10.1007/978-3-032-29473-9_8

perspective. It takes up this viewpoint with the express purpose of provoking a discussion around:

- What organizational structure and set of professionals will be most capable in making sense of the complex networked dynamics of tech innovation and coordinating meaningful diplomatic initiatives that alter these dynamics?

This question is set against the basic idea established in the economics of innovation that:

The locus for innovation is no longer considered to be the individual or the firm but increasingly the network in which a firm is embedded. Scientific and technological breakthroughs are now considered to result from numerous contributions of many actors working in networks. (Pittaway et al. 2004, 144)

We make the argument that the capacity of one or even several high-ranking officials to make sense of, act within, and effect change on dense networks of tech innovation actors in a practical way is likely to be limited. Rather than simply merging technology-based foreign policy ambitions with the established traditional diplomatic profile of an “ambassador” or “envoy,” MFAs would be better placed considering how such a figure can interrelate with and supplement broader networks of government activity within the MFA and embassies, in the domestic innovation ecosystem, at the site of posting, and with the national scientific diaspora. Indeed, networked thinking and organizational forms should be established at the beginning of organizational design rather than an afterthought following the keynote moment of envoy appointment.

The structure of the chapter is as follows. Firstly, we outline some of the factors lending complexity to technology as a foreign policy domain and characterize it as a highly dynamic and equivocal arena for diplomatic practice. Secondly, we acknowledge the recent formalization of tech ambassadors and envoys as a response to this policy domain. Thirdly, we introduce the sense-making perspective as a means to conceptualize the challenges these professionals face in refining what their policy priorities and practice should actually consist of. Thirdly, using the notions of organizational complexification and simplification, we argue that organizational adaption by MFAs should engage with the structure of networks as the locus of innovation and not simply fall back on the ambassadorial profile. Finally, we look to the future and provide some high-level suggestions for how MFAs may adapt their organizational structures and practices to the identified challenges.

Science, innovation, and tech diplomacy, as interrelated arenas of practice, hold the potential to bridge and mitigate points of tension in a global context of technological acceleration. However, doing so will require careful thinking around organizational adaption by MFAs so that they can become essential actors in this mix rather than bystanders to technological change.

2 CONTEXT: TECH FUTURES, COMPLEXITY, AND STATES

States are increasingly vested in the fruits of technological innovation and capitalizing on the possibilities derived from the frontiers of science. The deliberate cultivation of policies designed to build and incentivize interactions across the triple helix of state-academia-industry is pervasive across the globe. National strength is seen to rely on a complicity between science, innovation, and technology and the maintenance of thriving innovation ecosystems that bring these actors together to create new products, services, and, in turn, wealth (henceforth technovation) (Gardner et al. 2017; Powell and Snellman 2004; Beaudry et al. 2022). Technology is thus a highly dynamic policy domain as change is continually in motion both within and across tech verticals.

Technovation is often construed as a competitive issue by policymakers and can be galvanized by a mix of geopolitical and geoeconomic factors (Salter 2025). In the former case, novel technological advancements are understood as a means to defense and security advantage, while in the latter tech autonomy, economic catchup and increasing market share in a competitive and interdependent global context form the underlying rationale for state involvement (Weiss and Thurbon 2021; Thurbon and Weiss 2021). Given the dual-usage potential of many technology domains such as quantum, artificial intelligence (AI), and biotechnology, distinguishing where government security concerns end and prosperity ambitions begin can be challenging (Krelina 2021; Koplin 2023; Atlas and Dando 2006).

Sitting behind this demand for technovation lies the Collingridge dilemma. The societal implications of technologies are not fully evident when they are more embryonic and at a point of development, demonstration, prototyping, or initial scale-up, and it is at this point that controlling the technology is easiest. Once technologies are fully exploited and diffused at scale across domestic and indeed international markets, their implications become more evident, but governance interventions are far more complex (Genus and Stirling 2018). This highlights how policymaking organizations are often placed in a Catch-22 by the market potential of novel technologies, where competitive pressures exist to drive the enablement of technological change, but in turn create societal and governance challenges. Hence, locating the “national interest” in this mix is often confounded by the uncertainties of technological change.

Crucially, technovation is not just a matter for domestic policy given the reality that, in many cases, the processes and practices of technovation are distributed across national borders (Carayannis et al. 2016; Archibugi and Iammarino 1999). While states may possess competitive instincts and want to enhance their national technological capabilities and grow their markets, the international distribution of the raw ingredients behind technovation, including both Global Value Chains (GVCs), Global Innovation Networks (GINs), and Global Science Networks (GSNs), means that international collaboration will always be part of policy conversations. Recent debates around the role of computing power, or “compute,” as a potential limiter for the application of AI

and the material distribution of compute across national geographies are illustrative of this point (Lehdonvirta et al. 2024). Political expectations about “sovereign capability” for technology, i.e., national self-reliance and autonomy, are often challenged by the realities of technovation. Hence, technovation is also a matter for foreign policy with states looking abroad at both threats, possibilities, and issues of governance.

Overall, then, the policy portfolio of a high-ranking tech diplomat is likely to be complex in content and wide ranging in focus. The dynamics raised above are far from an exhaustive account of what makes tech a challenging foreign policy domain but does serve to illustrate the often-countervailing factors that will come across a tech diplomat’s desk. To assume that “tech” is a discrete, bounded, and static arena of foreign policy would be to underplay the forces of innovation and the input of science, the comingling of defense and civil technovation agendas, and the governance needs that lie beyond the horizon of technological change. Tech also challenges the traditional diplomatic preoccupation with regional specialization given its often geographically disembedded characteristics and reliance on transnational networks of activity (Krige 2019).

3 ORGANIZATIONAL ADAPTION IN MOTION?

In this context, a range of governments have moved to bed science and technology (S&T) into their foreign policies to respond to the international dynamics of technovation. This has included the creation of dedicated diplomatic postings for technology. As of 2022, 19 countries had appointed senior-ranking diplomatic officials with a dedicated brief for technology issues (TBI).¹ San Francisco predominates as a center of gravity for these postings. However this figure, now likely higher, of 19 countries does not take into account the fact that many MFAs have or are setting up formalized networks of more junior staff working on S&T issues. For example, the UK’s Foreign, Commonwealth and Development Office (FCDO) hosts the Science and Technology Network (STN). STN employs approximately 130 professionals embedded at embassies and consulates globally who work on a range of S&T-related diplomatic activities, including staff based in San Francisco. Whether based around a network or individual profile, new MFA initiatives are necessarily subject to ongoing organizational experimentation and the challenges of structural formalization.

As the Tech Diplomacy Global Institute (TDGI) has noted, there are at least three avenues to formalization: setting up a tech ambassador profile hosted by the MFA as in the case of Denmark; creating stand-alone entities

¹ Data drawn from the Tony Blair Institute, who define tech diplomats as the following:

For ease of discussion we will use the blanket term “tech diplomats” to cover the entire conceptual spectrum ... tech diplomats will be defined as diplomatic personnel affiliated with foreign-affairs ministries or departments, carrying the title of ambassador or special envoy, appointed specifically to lead work on technology-, digital-, or cyber-related foreign policies and strategies of states, with or without the support of a formal team or office.

outside of the MFA, such as Switzerland's Swissnex; or hybrid models combining elements of both, like Austria's Open Austria program. These "external" structural arrangements are then combined with different approaches to managing cross-ministerial interfaces domestically and the extent of integration in this regard given the cross-cutting features of S&T policy (TDGI 2026). While discussion of structure is important, we propose that sense, both individual and collective, is a key resource in ensuring the value of these initiatives. Given the idea presented in the introduction to this chapter that developments in S&T result from "many actors working in networks," working across these networks arguably holds the key to building an effective program of diplomatic activities. To frame this point further, we now introduce the sensemaking perspective.

4 SENSEMAKING AT THE GLOBAL FRONTIERS OF TECHNOVATION

This section briefly introduces the sensemaking perspective and connects it to the professional lifeworld of tech diplomacy. Given space constraints, the following conceptualization of sensemaking sidesteps various theoretical controversies that exist in the extensive sensemaking literature in order to provide a usable account of the idea in the context of this book chapter.

Sensemaking can broadly be described as the means by which an organization's operational context is given a "face" so that it can be acted upon. The existence of an organization and the capacity of its constituent professionals to *keep things moving* is dependent on sensemaking. As organizational theorist Karl Weick proposed, rather than necessarily focusing on the epistemic threshold of "truth," what is required for effective sensemaking is a "good story" (Weick 1995, 60–61). Without a narrative that straddles the activities of individuals and teams in an organization, the processes and thus accomplishments of that organization come under threat and are prone to breakdown (Weick 1995, 15). As Maitlis and Christianson put it, sensemaking is:

a process, prompted by violated expectations, that involves attending to and bracketing cues in the environment, creating intersubjective meaning through cycles of interpretation and action, and thereby enacting a more ordered environment from which further cues can be drawn. (Maitlis and Christianson 2014, 67)

Weick proposed that sensemaking is often most required in an organization when the normal state of affairs has been disrupted by an anomalous event which challenges routine operations and ways of working (Weick 2006, 1731). The very requirement for MFAs to adapt to new technological innovations and their implications in global affairs is an instance of sensemaking under challenge, as these established organizations attempt to reformulate themselves to understand and respond to unknown political and policy issues pertaining to tech.

The following quip from US Secretary of State Anthony Blinken is indicative of this challenge, as he talked in 2024 to the demands of conducting foreign policy in the context of transformational technological change:

I got to the point where I needed scientists and technologists at the table just to tell me whether I needed scientists and technologists at the table ... I can't remember a period of time when we had a greater multiplicity of challenges and a greater complexity of challenges and an interconnectedness among those challenges. (Blinken 2024)²

Building a shared conception of plausibility, or “map of a shifting world,” is at the heart of sensemaking (Ancona 2012). But how can a map be formulated when the context of operation is continual innovation, scientific advancement at the frontiers of knowledge, and technological disruption? Can a single tech envoy and their team, no matter how qualified, really be expected to make sense of these dynamics across numerous tech verticals and trace their roots in the dense and translocal networks of tech innovation value chains?

5 ORGANIZATIONAL SIMPLIFICATION OR COMPLEXIFICATION?

In a recent study on the challenge of complex problems for policy organizations, Joosse and Teisman set up a dichotomy between organizational simplification and organizational complexification. On the one hand, *simplification* refers to the way in which state bureaucracies have a tendency to respond to complexity by dividing it into simpler and more manageable components. This can manifest as a simplification in problem definition, a simplification in organizational processes, or a simplification in organizational structure. They argue that this creates artificially “bounded problems” and is likely to drive path dependencies in organizational practice rather than open up creative responses (Joosse and Teisman 2021, 845).

Depending on the extent to which newly employed tech envoys are networked into the wider MFA organizational architecture, the innovation ecosystem domestically and at post, and the dedicated support staff at their disposal, the act of hiring a single tech ambassador for a regional posting is on the surface an act of organizational simplification. Rather than meeting complexity with “requisite variety,” MFAs pursuing the ambassadorial route are centralizing and placing the demands of sensemaking onto one high-profile individual (Weick 1995). The capacities of this individual to engage with the complexities of technovation, bracket cues in their environment, and tell this story across the MFA are naturally finite.

²Blinken's statement mirrors the idea of highly complex (sometimes referred to as “wicked”) policy challenges as “sets of interrelated problems and sub-problems that develop non-linearly and dynamically and involve a variety of different, interdependent actors” (Joosse and Teisman 2021, 846).

This is not to say that no obvious value is apparent from setting up these new positions. Tech ambassadors employed to date generally come with an eminent background and well-established networks either in the scientific, diplomatic, or technological spheres. They likely have a high level of social capital, both in virtue of their professional training, network position, and the prestige of taking up a novel state posting. Yet by responding to the challenge of technovation with a traditional mode of organization, albeit with a new remit, tech envoys risk becoming a bottleneck to action.

Sensemaking is an inherently social activity, and the complexity of technovation demands more sociality not less. As Weick and others have suggested regarding the idea of “requisite variety,” making sense of a complex world requires an internal organizational system that is equally complex (Weick 1995). This raises the idea of organizational *complexification*, which Joosse and Teisman describe as:

...the widening of the scope of problems and solutions by combination and integration; the opening up of processes by adapting to emerging events and improvisation; and a broadening of structures by involving a variety of actors and building relations based on the added value actors bring in. (Joosse and Teisman 2021, 847)

Instead of falling back on traditional modes of organization and practice, complexification necessitates deeper organizational change which tries to grow with, rather than work against, the complexity of the policy environment. Ambiguity should be embraced by design rather than compartmentalized through rigid role definition and hierarchical activity. This, they argue, allows for path creation as new avenues for action can be generated through the heightened volume and form of professional interactions enabled. Naturally, this organizational decentralization and distribution of sensemaking in the domain of foreign policy will come with managerial challenges in terms of coordination, and risks in the context of an increasing securitization of the fruits of science by governments across the globe.

However, taking this line of thinking and applying it to the problem of resourcing a technology-literate foreign policy challenges MFAs to think beyond the creation of tech envoys. It also demands further research into the ways in which sensemaking in experimental and networked forms of organization have had success and could be applied by MFAs, both within the context of technovation and also across other policy contexts. Many insights already exist in the extensive organizational sociology and innovation studies literature, albeit mostly with a domestic rather than foreign policy focus. For example, the role of cross-organizational sensemaking in understanding emerging technologies (Gattringer et al. 2021; Seidl and Werle 2018), how different professional groupings make sense of frontier technologies such as artificial intelligence (AI) (Scarborough et al. 2024), and the role of communities of practice in catalyzing and governing technological innovations (Swan et al. 2002).

Overall the challenges outlined in this chapter demand sensemaking with networked characteristics that maintains the strengths of traditional diplomatic competencies such as convening, communicating, and negotiating (Berridge 2015). At the same time, cross-fertilization is needed between the sensemaking activities of MFAs and the actors, such as universities, R&D intensive corporate ventures, venture capitalists, startups, scientists, and so on, who drive technological innovation in the first place.

6 LOOKING TO THE FUTURE

MFAs need to respond to the globalized dynamics of technovation that will drive future diplomatic challenges. While the practicalities of organizational change will always be subject to resource constraints, this merely reinforces the need for creative thinking. We have opened up a discussion around the role of complexity in organizational adaption and hope that this provokes further debate on and research into the application of sensemaking to the challenging foreign policy domain of tech.

While there is no doubt value in merging technovation ambitions with the traditional ambassadorial profile, such a move can only be part of the puzzle. Navigating the densely networked architectures of technological change will rely on networked modes of organization, collaborative sensemaking, and an acknowledgement that complexity is the name of the game. Sense, order, and meaningful action are unlikely to be found in the hands of a few high-powered individuals. To this end, we make the following high-level recommendations to MFAs with or considering employing science, innovation, or technology-oriented diplomatic professionals:

- Science, innovation, and technology are interconnected phenomena. Professional role definitions and responsibilities should reflect this by design rather than creating silos for diplomatic operation.
- New diplomatic professionals will require horizontal forms of expertise that straddle deep knowledge verticals and allow for competent engagement across the triple helix of academia, the private sector, and government and between priority science and tech domains. This should combine with knowledge of culture, place, and history well established in the organizational memory of MFAs.
- MFAs should experiment with networked and decentralized forms of organization and distributed leadership structures that allow for agile engagement with fast-moving technological challenges.
- MFAs should exploit their convening power and global organizational footprints to create docking points and build networks, and ideally communities of practice, across geographically dispersed triple helix systems.
- MFAs should strive for internal clarity around domestic technovation capacities and national interests versus governmental values regarding science and tech, and their interrelationship with cross-border diplomatic

challenges. Balancing values and interests is key to creating clarity within foreign policy frameworks that set parameters for action.

With clear leadership and creative thinking, MFAs can embed themselves as central actors in networks of technological change. In turn and through collaborative modes of sensemaking, they can then develop science diplomacy initiatives that integrate diverse actors and knowledge systems for mutual benefits at the international scale. However, developing these organizations of the future will require ongoing collaborations and research initiatives with scholars of organizational design and an openness to ways of working outside of the traditional diplomatic toolbox.

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The Place of Professional Societies in Science Diplomacy

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1 INTRODUCTION

National and international professional societies have a vital role to play in science diplomacy. They enable and support scientists to contribute to the policy objectives of their country. International co-operation between scientists is facilitated by professional societies outside the constraints of formal diplomacy.

For each of the three categories of science diplomacy proposed in 2010 (science for diplomacy, science in diplomacy, and diplomacy for science) (AAAS and The Royal Society 2010) to be effective, there is a need for scientists within a country to be part of a robust national network of professional societies that interacts with the appropriate international organizations. Although the 2010 taxonomy of science diplomacy has been recently updated (AAAS and The Royal Society 2025), in this chapter, we use the earlier classification.

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2 SCIENCE FOR DIPLOMACY

The use of science as a soft power to advance diplomatic objectives is exemplified by the development of regional federations to facilitate people-to-people exchanges and regional trade. The Federation of Asian Chemical Societies (FACS), for example, was established in 1979 at the initiative of UNESCO and brought together the national chemical societies of over 30 countries in Asia, extending from Jordan and Israel in the West, China in the North, New Zealand in the South, and the countries of South and Southeast Asia.

This example is the story of how the interests of individual chemists and their institutions aligned with the interests of the chemistry profession, governments, non-government aid organizations, and UNESCO and led to the formation of the Federation of Asian Chemical Societies.

The Second World War (1939–1945) left countries in Asia devastated. Many were colonies, and all these except Timor-Leste (United Nations Security Council 2001) achieved independence in the two decades after the war. The diplomatic imperative of past colonial powers and the countries within the region was to develop the capacity and capabilities of people in these countries to set them on the path of reconstruction and development.

The United Nations, through the Economic Commission for Asia and the Far East (ECAFE) and UNESCO (Duedahl 2016), was an important player in this long-term development as was the Commonwealth of Nations, an international association of member states that were former territories of the British Empire.

The Role of the Commonwealth of Nations

In January 1950, the Commonwealth of Nations held the Commonwealth Conference on Foreign Affairs (Oakman 2010) in Colombo, Ceylon (now Sri Lanka). Ministers from Australia, Canada, Ceylon, India, New Zealand, Pakistan, South Africa, and the UK met to discuss how to plan and deliver aid to the developing countries. The outcome of the meeting is known to this day as the Colombo Plan, which commenced in January 1951. One aspect of the Colombo Plan that is still in existence today was the awarding of scholarships to students to enable their tertiary education overseas. These students undertook both undergraduate and post-graduate degrees in their host country and often returned home to academic posts, enabling the dissemination of knowledge, and thus developing the capacity and capabilities of people. Many of these students wished to continue their research when they returned to their home countries but were often hampered by lack of equipment and mentors. This affected people in all disciplines with the science disciplines particularly affected by lack of equipment. Here, we focus on the field of chemistry.

The Role of UNESCO

Along with the Commonwealth of Nations, UNESCO was also active in the region (Fennell et al. 1984; Freemantle et al. 1993). A key UNESCO operative was John Kingston (Spurling and Webb 2015). John Kingston was born in Dublin in 1937 and came to Australia in 1962 to do his PhD at the University of New South Wales after completing his MA in Chemistry at Trinity College, Dublin. He then spent 2 years at Imperial College London before returning to Australia at La Trobe University in Melbourne. In 1969, he left Australia to accept a position as Professor of Chemistry and UNESCO expert at the University of Jordan before transferring in 1974 to UNESCO Headquarters in Paris as the program specialist in the chemical sciences.

UNESCO had been strengthening regional chemical research potential in Asia since 1960. Their method was through supporting regional symposia such as the Asian Network on Medicinal Plants, Spices, and other Natural Products (ASOMPS) with the first symposium held in Peshawar, Pakistan. UNESCO also sponsored events in donor countries, such as a Workshop Conference on “Biosynthesis of Natural Products” in Canberra in August 1976 and a Congress on “The Role of Laboratory Teaching in University Chemical Courses” in Perth, Australia, in February 1978 (Cole et al. 1978).

John Kingston realized that while such events had their place, they did not achieve the necessary long-term capacity building. So, he proposed the idea of establishing and delivering programs through networks. The first such network, established in 1974, was the regional network for the chemistry of natural products in Southeast Asia. However, in the 1970s, it became clear to Kingston and others that the combination of symposia and networks would still not achieve the long-term goals of regional cooperation and capacity building (noted in correspondence by Kingston).

So, the concept of a Federation of Asian Chemical Societies (FACS) emerged (Noller et al. 2004). This Federation was the first of its kind in the region and paved the way for other fields of science to adopt the model in order to foster and advance science and science diplomacy in the Asia Pacific region. These included:

- Association of Academies and Societies of Sciences in Asia (AASSA): a non-profit organization that was formed in 2012 through the merger of the Federation of Asian Scientific Academies and Societies (FASAS) and the Association of Academies of Sciences in Asia (AASA)
- Federation of Asian and Oceanian Biochemists and Molecular Biologists (FAOBMB): an organization founded in 1972 that promotes biochemistry and molecular biology in the Asia-Pacific region
- Federation of Asian Polymer Societies (FAPS): An organization that promotes polymer science in the Asia-Pacific region
- Asia-Oceania Federation of Organizations for Medical Physics
- Southeast Asian Federation of Organizations of Medical Physics
- Asian Federation of Biotechnology

- Asian Federation for Pharmaceutical Science
- Federation of Asian-Oceanian Neurosciences Societies
- Association of Asia Pacific Physical Societies

Kingston called for representatives of societies to participate in a working party for the proposed Federation. This took place at Mahidol University in Bangkok in December 1978. The meeting was attended by representatives from the chemical societies of Australia, Hong Kong, Indonesia, India, Iraq, Malaysia, the Philippines, Singapore, South Korea, and Thailand. The meeting agreed to form the Federation, and this was achieved in 1981 (Noller et al. 2004). New Zealand and Japan joined in 1981, and both the Chinese Chemical Society, Beijing, and the Chinese Chemical Society located in Taipei joined in 1984.

There are now 32 societies in the FACS (Federation of Asian Chemical Societies 2026) stretching geographically from the Turkish Chemical Society in the West to the Chemical Society of the South Pacific in the East and from the Mongolian Chemical Society in the North to the New Zealand Institute of Chemistry in the South (Spurling et al. 2020). Türkiye held the 19th Asian Chemical Conference in Istanbul in 2023.

With the support of professional societies, chemistry has flourished in Asia since 1981. Research publications in chemistry in Asia, as a percentage of global publications, have gone from 20% in 1980 to 62% in 2023 (Spurling and Webb 2020) as shown in Fig. 9.1.

3 SCIENCE IN DIPLOMACY

The direct support of diplomatic processes through science is illustrated by the role the chemistry profession through both industry associations and professional societies played in negotiations for a Chemical Weapons Convention (CWC). A comprehensive CWC was finalized in 1997.

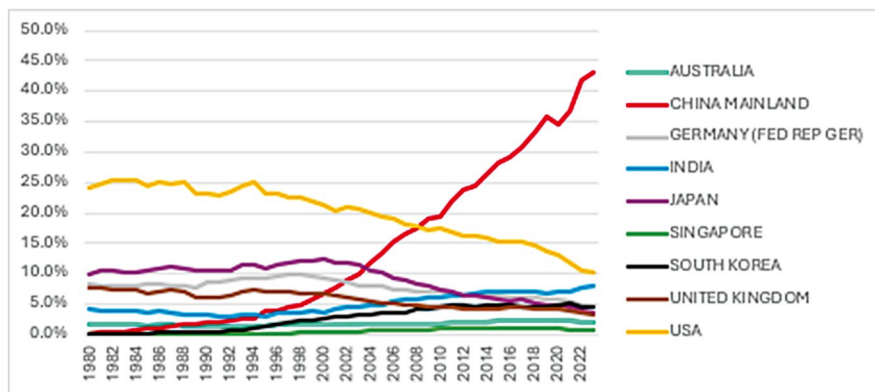


Fig. 9.1 <http://clarivate.com/products/web-of-science/>

As we illustrate below, the diplomatic imperative, which emerged strongly after the first World War, was to eliminate the use of chemical weapons. The need for the elimination of the use of chemical weapons is not new as the use of poisons and diseases as weapons goes back a long way (Mathews 2016; Carus 2017).

Many human societies have had rules to govern their relationships with other societies, particularly when it comes to conflicts. Early examples include the Indigenous Australians aborigines who had a well-developed communication system (White and Kirkhove 2020; Lee 2025). These rules are now referred to as the Law of Armed Conflict (LOAC). A comprehensive account of how these rules apply nationally and internationally can be found in a publication of the Australian Defence Force (Houston 2006).

The Indigenous Australian code did not mention a ban on poisons (note that a clear distinction between chemical and biological weapons did not emerge until the twentieth century), but as early as about 500 BCE, the Hindu Laws of Manu in oral form recorded constraints on poison weapons (Jefferson 2014). The use of poisoned weapons in war found its first codification in Article 57 of the Strasbourg Agreement of 27 August 1675, by which French and German forces, and their respective allies, agreed to prohibit the firing of poisoned bullets and to severely punish any soldier using such munition (Zanders 2003). Although it applied only to the USA, the Lieber Code of 1863 was influential in subsequent LOAC (Lieber 1863). Dr. Francis Lieber drafted the “Instructions for the government of armies of the United States in the field” for President Lincoln in response to the civil war. His Article 16 expands the notion of “military necessity” to exclude cruelty—that is, the infliction of suffering for the sake of suffering or for revenge, nor of maiming or wounding except in fight, nor of torture to extort confessions. It does not admit of the use of poison in any way, nor of the wanton devastation of a district. It admits of deception but disclaims acts of perfidy; and, in general, military necessity does not include any act of hostility that makes the return to peace unnecessarily difficult.

The next iteration of a formal codification occurred when 15 European nations met in Brussels on August 27, 1874, and agreed to an International Declaration concerning the Laws and Customs of War. This included two articles (12 and 13) concerning “means of injuring the enemy.” They were:

Article 12. The laws of war do not recognize in belligerents an unlimited power in the adoption of means of injuring the enemy.

Article 13. According to this principle are especially “forbidden”:

(a) Employment of poison or poisoned weapons

The Brussels agreement of 1874 was agreed to at the meeting but never adopted as a binding convention. It did, however, provide the basis for discussions at the Hague peace conferences of 1899 and 1907. The Second Hague Conference in 1907 agreed to 13 Conventions and 1 declaration concerning

all aspects of conducting warfare at the beginning of the twentieth century: Convention (IV). Regulations concerning the Laws and Customs of War on Land (The Hague, 18 October 1907) included (International Committee of the Red Cross 1907):

Article 23. In addition to the prohibitions provided by special Conventions, it is especially forbidden:

- (a) To employ poison or poisoned weapons; and
- (e) To employ arms, projectiles, or material calculated to cause unnecessary suffering

Despite this agreement between nations, gas was used extensively by all belligerents in the First World War.

Public debate on the use of chemical weapons developed in the immediate post-war years. There were two points of view. The League of Nations Permanent Advisory Commission on Military, Naval and Air Questions in a report to the League condemned the use of chemical weapons on non-combatants but argued that gas was no crueler than any other methods of warfare against combatants. The alternative view promoted by, among others, the International Committee of the Red Cross (ICRC) was that use in war of asphyxiating, poisonous or other gases, and of all analogous liquids, materials, or devices, has been justly condemned by the general opinion of the civilized world.

In 1921, the League of Nations set up the Temporary Mixed Commission on the Reduction of Armaments (TMC) to investigate how to control international trade in arms, munitions, and implements of war. In September 1924, the Assembly of the League of Nations asked that the draft convention produced by the TMC be submitted to both member and non-member governments. This was done in May of 1925 at the Geneva Conference for the Supervision of the International Trade in Arms and Ammunition and in Implements of War. At the start of the conference, the US delegation placed on the agenda the restriction in trade of chemicals with chemical weapons applications, suggesting that all international trade in gas weapons should be prohibited. The US proposal was not accepted, but the Geneva conference did agree to outlaw the use of chemical and bacteriological weapons. The Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases and of Bacteriological Methods of Warfare was signed on June 17, 1925 (International Committee of the Red Cross 1925).

In the nineteenth and early twentieth centuries, scientists of many disciplines had started organizing themselves into groups and associations both nationally and internationally. The British Association for the Advancement of Science (BAAS) was formed in 1831, the Chemical Society (CS) in 1841, the Société Chimique de France (SCF) in 1851, and the American Chemical Society (ACS) in 1876. These societies were mainly concerned with disciplinary matters, but two interventions in the 1920s are of note.

Sir T Edward Thorpe was the chief chemist to the British Government from 1894 to 1909 and president of BAAS in 1921. He concluded his presidential address to the 89th meeting with a strong argument against the use of chemical weapons. He ended with the words: “This Association, I trust, will set its face against the continued degradation of science in thus augmenting the horrors of war. It could have no loftier task than to use its great influence in arresting a course which is the very negation of civilisation.”

The second intervention was in 1925–1926 when the American Chemical Society conducted a successful campaign to persuade the US Senate not to ratify the Geneva Protocol despite the fact that their government was recommending ratification (Jones 1980). The three main arguments used were the comparative humanity of chemical warfare, the need to be prepared in this area for future wars, and the control that the League of Nations might acquire over the chemical industry in the United States.

Whether it was because of concerns about “retaliation in kind” or respect for the provisions of the 1925 Geneva Protocol, there was no use of either chemical or biological warfare in the European theatres during the Second World War (Mathews 2016). There was the use of atomic bombs on Hiroshima and Nagasaki in 1945, and the potential of these weapons to wreak havoc on humanity led to a prioritization on nuclear issues. The treaty on the non-proliferation of nuclear weapons was signed in 1968, and the Conference on Disarmament (CD) turned its attention to biological and chemical Weapons. They separated the two types of weapons, and the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction or Biological Weapons Convention (BWC) was signed in April 1972. The Conference on Disarmament then commenced negotiations on a Chemical Weapons Convention (CWC). Work began in earnest on the text of a CWC in 1980 when the CD established an Ad Hoc Working Group to discuss and then negotiate a draft treaty (Mathews 2016).

The negotiations proceeded slowly until 1984 when the newly mandated Ad Hoc Committee on Chemical Weapons moved away from exploratory discussions to the development of a CWC text. This led to the introduction of the “rolling text,” which was considered from one annual meeting to the next annual meeting.

A change of foreign minister in the Australian Government in 1988 was to have an unexpected effect on the CWC process. Senator Gareth Evans was appointed to the post when his predecessor was appointed governor general. Evans and his officials came to the conclusion that the “rolling text” was in fact close to a workable document, and they produced a cleaned-up version.

Their other insight was that a CWC would not succeed without the support and cooperation of the chemical industry and the chemistry profession. That is to say, the diplomatic objective required the cooperation of science and technology. The Australian Government hosted the Government Industry Conference Against Chemical Weapons in Canberra in 1989. The conference

had 375 delegates from 66 countries and 4 organizations. These organizations included the International Federation of Chemical, Energy, and General Workers Unions and the European Chemical Industry Federation.

In his opening address, Senator Evans remarked (Australia Department of Foreign Affairs and Trade 1989, p. 6):

But even the accumulated hundreds of years of negotiating man-years in Geneva, and the kind of demonstration of political will that was involved in Paris, will not be enough to carry the convention making process through to its fruition unless that political will is accompanied by what of our discussants has very nicely, and accurately, called practical will. What governments now have to do is seize the opportunity created by the constellation of forces now coming together in favour of a comprehensive Convention-political, military, technical, and industrial-and get down to converting good intentions into practical, workable, treaty language, and to do so within a finite time frame rather than the permanently receding time horizon with which we have become all too familiar. The point of this conference is, above all else, to help create the environment for injecting that practical will.

He went on to say: "This conference is unique because it has brought together not only diplomats but representatives of industry in a consultation intended to advance negotiations which are usually considered to be the sole preserve of governments." This is an eloquent statement of "science in diplomacy."

4 DIPLOMACY FOR SCIENCE

The use of diplomatic action to facilitate international scientific collaboration will be illustrated by arrangements for the harmonization of measurement standards and agreements to ensure interchangeability and interoperability. These are both diplomatic and consumer protection imperatives.

Our third example of the interaction of science and diplomacy comes from a field somewhat different from the two cases discussed above, namely, that of measurement. Its significance has seen its specialization, metrology, take a central role in countries for which trade is a core activity.

Measurement is one of the earliest scientific areas that demanded international collaboration, recognized by many countries as essential for trade and commerce. In the early nineteenth century, John Quincy Adams (the sixth US president from 1825 to 1829) wrote in a report to the US Senate in 1821: "Weights and Measures may be ranked among the necessities of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry" (Todd 2004).

The Weights and Measures Act of 1824 in the UK sought to bring order to the diversity of measures; for example, the imperial gallon defined in the Act would replace the four different gallon measures in use at that time in England: the Winchester corn gallon of 272 1/4 cubic inches; the Winchester liquid

gallon of 268 $\frac{4}{5}$ inches; the wine (and spirit) gallon of 231 cubic inches; and the ale gallon of 282 cubic inches (Todd 2004). Trade and customs clearly needed consistency. Another example of the importance of interchangeability/ interoperability is provided by Todd (2004) concerning the construction of a small arms factory in Lithgow, Australia:

In 1909 the American firm Pratt and Whitney was contracted to supply all the equipment for the Lithgow plant to specifications that would ensure interchangeability of components with British rifles. But the parts would not fit because no one told the Americans that the British drawings used two different standards of length: dimensions above 2 inches were expressed in inches aligned with the imperial yard, but dimensions below 2 inches were based on the 'Enfield inch', a standard used by the Royal Small Arms Factory at Enfield.

In the Australian context, as previously independent colonies agreed to unite and form the Commonwealth of Australia in 1901, measurement was considered so important that it was written into the Constitution of the newly independent country. Thus, Subsection (xv) of Section 51 of the Constitution specified that the Parliament should have the power to make laws relating to weights and measures (Wright 1988).

The scientific community had recognized this issue in the nineteenth century. Various proposals for internationally recognized systems of measurement were considered. In 1875, the Metric Treaty was signed by 17 nations. They agreed to establish an international bureau for weights and measures as the repository of the international standards for the meter (the measure of length) and the kilogram (the measure of weight). An international committee was also established as well as periodic General Conferences on Weights and Measures to widen the acceptance of the standards. Almost 100 years later, in 1947, Australia became a signatory to the Metric Treaty, and senior Australian scientists became actively involved (Todd 2004).

The scientific field of chemistry was also developing relevant chemical standards: expansion of chemistry in the nineteenth century led to initiatives in international cooperation. The earliest (perhaps the first) conference convened in Karlsruhe, Germany, in 1860 to reach agreement on the theory of organic chemistry, especially the naming of chemical compounds. The first international congress on applied chemistry was held in Brussels in 1894; a series of meetings on the standardization of atomic weights and constants occurred in the 1890s and early 1900s. Standardization was seen as essential for progress in the field of chemistry research and development.

William Percy Wilkinson, the Australian Government analyst, attended the eighth triennial Congress on Applied Chemistry held in Washington and New York in 1912. Wilkinson was sent by the Government. His position was a senior one within the Department of Trade and Customs. Income from customs and excise was a significant source of funding for the new government: Revenue from customs and excise accounted for 73% of Commonwealth revenue in 1901–1902, rising to 75% in 1906–1907. The relative amount

gradually decreased in subsequent years as the Commonwealth gained some income taxing powers (Spurling and Webb 2017).

International collaboration to establish and maintain scientific standards led to the formation of international organizations, or unions, such as the International Union for Pure and Applied Chemistry and the International Union for Pure and Applied Physics, among others, that remain very influential in these traditional fields of science (Spurling and Webb 2018). All such professional associations are challenged by the increasing digitization of science and communication more widely. It is here that the work of the Institute of Electrical and Electronics Engineers (IEEE) and its Standards Association is critical. Although established as a US-based organization, its global reach has meant that it has, *de facto*, a key role in standardization of digital communications technology. This became critical in the efforts of the Australian science research organization CSIRO (Commonwealth Scientific and Industrial Research Organisation) to commercialize its Wi-Fi technology and provides our third example of ways in which professional associations are important in international matters.

The core Wi-Fi patent came from work by CSIRO radio astronomers studying gravitational waves associated with exploding black holes. The patent, issued in the late 1980s, was titled “A Transform Processing Circuit,” describing a semiconductor chip that would carry out Fast Fourier Transforms (FFT) and Inverse Fast Fourier Transforms (IFFT). Wi-Fi was a set of standards adopted by the IEEE, which both promulgates standards and records relevant patents.

Subsequently, CSIRO developed for commercialization a chip to rival the speeds of wired networks using FFT/IFFT technology. The first functional microcircuit was successfully developed by 2000 in collaboration with a small startup company Radiata. The IEEE had developed new standards, and CSIRO agreed to grant licenses to firms promoting the standards.

As Healy (2019) (CSIRO) noted: “Perhaps naively, CSIRO expected firms to take licenses under its patents and pay modest royalties. But, oddly, no one signed a license; even though many were using the technology.”

CSIRO’s test case against a mid-sized infringer led to a pair of lawsuits against CSIRO. The plaintiffs were significant players in this technology. The lawsuits sought declarations that “the CSIRO’s Wi-Fi patent was invalid and/or that the plaintiffs did not infringe.” The plaintiffs were Apple, Microsoft, Hewlett-Packard, Intel, Dell, and Netgear. If CSIRO ever needed confirmation that its Wi-Fi patents were indeed very valuable, then it clearly had it. The litigation lasted for 12 years.

The standards set by the IEEE played a key role in both developing this technology and in resolving the legal dispute. As digital electronic communication capabilities continue to develop, the IEEE will have much to consider. For example, its Web site recently announced that the IEEE Standards Association will address the assessment of the trustworthiness of artificial intelligence (AI) systems.

5 PROFESSIONAL SOCIETIES: ADVOCATING AND FACILITATING DIPLOMACY

These three examples serve to highlight the breadth of the historical contribution of science to diplomacy. The story of the Federation of Asian Chemical Societies is one where formal networks at a national level contributed to international scientific collaboration driving regional economic prosperity at an international level, achieving national government objectives. The story of the Chemical Weapons Convention is a story of how scientists can inform humanity how to modulate the brutality of war. By sharing scientific information and by gaining consensus between academics and industrialists within individual countries first, consensus was achieved among many countries. The Wi-Fi story highlights the needs and complexity of building common physical measurement standards to allow commercial exploitation and diffusion of technology.

The challenge is in how to build these solutions effectively and in a way that prepares for and informs future challenges. At perhaps the most basic level, the national governments must have a way of understanding the science in complex issues before they can establish dialogue with other countries to achieve diplomatic ends. Professional scientific societies, academic or industrial, within a country provide that source of focused, credible, accessible knowledge. The networks in international science are also such that respected scientists in any one country are credible and respected internationally. Often individuals in national professional societies find that they contribute to international discussion by way of membership or other participation in international professional societies. The Colombo Plan discussed above provides a good illustration of this from a Southeast Asian perspective where it is common for the relationships established through education of Asian scientists in Australia to endure throughout entire careers. This means that there can be a shared international understanding of the science among scientists (industrial and academic). Indeed, there are many examples of international scientific discussion under the structure of a professional society leading to the identification of emerging major global threats. Governments are then alerted to the challenges facing the world and can begin the necessary diplomatic process to provide a response, using the power of science.

Scientists undertake their work with a view to improving the world we live in. That can surely be done through the creation of new technology. That technology then needs to be shared among nations by productive and well-considered mechanisms. Professional societies provide a pathway for that diplomacy and an opportunity for scientists and governments together to create that better world.

Acknowledgments The authors wish to thank Adam Finch of CSIRO for preparation of Fig. 9.1.

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The Global Network of Internet and Society Centers: Science Diplomacy in an Era of Technological Disruption

Sofie Schönborn , Armando Guio Español , and Urs Gasser

I INTRODUCTION

Analyzing and addressing regional, national, and global societal challenges requires not only multilateral cooperation but also the integration of diverse actors, including those from scientific, diplomatic, and policy domains. Despite the increasing recognition of science diplomacy as a critical tool for international collaboration, there remains a limited understanding of the specific contributions and impacts of various initiatives within this field. This chapter aims to contribute bridging this gap by introducing the Global Network of Interdisciplinary Internet & Society Centers (also Network of Centers) (NoC) as a case study, an alliance of (mostly) academic institutions established in 2012 operating at the nexus of (digital) technology and society issues. While not explicitly conceived as a science diplomacy effort, we seek to explore the

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role of NoC in facilitating international dialogue, informing policy development, and supporting capacity building across different governance levels. Broader lessons from the network's practices might enhance our understanding of the potential and challenges of science diplomacy initiatives among academic institutions in addressing global issues. It is important to note that this contribution is not offering a comprehensive discussion of the NoC and its evolution but rather examines it through the looking glass of science diplomacy.

2 FORMATION AND EVOLUTION OF THE NoC

The NoC was incubated in 2012 as a collaborative initiative among a group of ten academic institutions from the USA, Latin America, Europe, and Asia. Its launch was motivated by the need to gain a deeper interdisciplinary understanding of the complex societal challenges and opportunities brought by the Internet. Since its inception, the NoC has evolved significantly in scale and scope, for instance, by bringing together more than 100 organizations and expanding its purview to include AI in response to the rapidly shifting landscape of global technology and governance. This evolution also reflects the network's commitment to aligning its mission with emerging global needs and contributing to the ongoing debates on global technology governance.

Rationale for the Formation of the NoC

The Internet and the shifts in the information ecosystem—and in society more broadly—it facilitated became a topic of academic inquiry since its inception. However, in the mid- and late 1990s, academic institutions were struggling to “locate” research on Internet and society issues as a complex socio-technical amalgam within the traditional disciplinary and departmental structures. Around the same time, several new and decisively interdisciplinary—and at times anti-disciplinary—academic units began to emerge, often bringing together individual researchers with a shared interest in Internet and society issues who in their home departments did not find communities of interest and practice. During the early 2000s, individual researchers affiliated with the growing number of academic institutions intensified collaborations with other researchers across geographies and continents, recognizing the global dimension of the Internet and the research questions that emerged from it. The thickening web of individual researchers from different disciplines and origins facilitated important research output and, above all, set the stage for trusted communities of practice over the course of a decade. However, as the Internet gained strategic importance for both governments and businesses, a group of academic leaders involved in running centers, building international communities, and supporting network building realized that a more institutional approach was needed—building upon the individual connections—to enhance

public interest research capacity on Internet and society issues and ensure that academia could more effectively inform increasingly contested and consequential decisions by policy-makers in the public and private sectors, both in local and global arenas.

Formation and Initial Participating Centers

A “Symposium on Internet-Driven Developments: Structural Changes and Tipping Points,”¹ hosted by the (now) Berkman (Klein) Center for Internet & Society at Harvard University (BKC) in collaboration with seven other Centers, served as the crystallization point of the launch of the NoC (BKC 2012). The event, which took place on December 6–8, 2012,² on the Harvard Law School Campus, brought together representatives from academic institutions—and a few partner organizations—across 5 continents and 22 countries. The symposium facilitated interdisciplinary discussions on the impact of the internet on the global information ecosystem and laid the groundwork for future collaborations in research, teaching, and policy engagement (BKC 2012). The event also served as a platform for participants to discuss the structure, goals, and possible future activities of the network, culminating in the launch of the NoC.

Guiding Principles and Governance

The NoC did not only bring together academic organizations studying the Internet and shaping its development but also found inspiration in the design principles of the early Internet standardization organizations, including the Internet Engineering Task Force (IETF) with its informal governance structure. Since its launch, the NoC has operated as an informal network with a light touch governance structure, consisting of a set of guiding principles, a steering committee (later re-named executive board), and an initially rotating, now permanent, Secretariat. The guiding principles of the NoC are openness, collaboration, and diversity, ensuring independence from governmental, political, and economic influences.³ The executive committee is composed of peer-academic colleagues and is a space for deliberation to reach strategic decisions such as the Networks roadmaps and new participating center admission. Administrative leadership within the NoC is now concentrated in a permanent Secretariat led by an Executive Director. The main activities of the NoC—with

¹ This event was funded by the John D. and Catherine T. MacArthur Foundation and the Ford Foundation.

² The co-hosting Centers included the Alexander von Humboldt Institute for Internet & Society, the Centre for Internet and Society Bangalore, the Center for Technology & Society at the Fundação Getulio Vargas Law School, KEIO University SFC, the MIT Media Lab, the MIT Center for Civic Media, the NEXA Center for Internet & Society at Politecnico di Torino, and the Berkman Center for Internet & Society at Harvard University.

³ For details, see https://networkofcenters.net/guiding_principles

the support of the Secretariat—is driven by participating Centers, ensuring that the network remains dynamic and responsive to changing global contexts. This governance structure has been pivotal in supporting the network’s mission to foster collaborative research while maintaining the autonomy and diversity of its participating Centers. A new governance structure that seeks to invite broader engagement by the Centers in NoC-wide activities—such as community building and public engagement—and enable varying contributions to networked efforts was discussed at the NoC Annual Meeting 2024 and is currently entering the implementation phase.

Expansion and Current Participating Centers

Since its founding, the NoC has grown from a small group of centers to a global network that now includes 72 centers and 53 affiliated organizations as of 2025.⁴ Initially, the network expanded “by invitation” based on existing collaborations, ensuring trusted participation and substantive collaboration. Over time, an “open door” policy for new participating Centers facilitated exponential growth while also introducing variability in the levels of engagement. To be able to support the rapidly growing number of participating Centers, and ensure alignment with mission and principles, the NoC has since developed a set of admission criteria and an approval process to guide future expansions.

A variety of activities within the NoC contribute to the network’s broader impact in different ways. First, the Secretariat plays a key role as facilitator, collaborating closely with participating Centers to coordinate network-wide initiatives and provide strategic guidance. Second, collaborative projects undertaken by multiple centers within the NoC—often peer led by one of the centers—allow for diverse academic institutions to pool their expertise in addressing complex, interdisciplinary challenges. Third, regional hubs in Europe and in Asia have been incubated to foster localized engagement. Finally, individual centers within the NoC initiate their own projects, which can generate network effects by inspiring or informing related work across the broader NoC community.

The networked approach of the NoC, guided by its principles of openness, collaboration, and diversity, enables interdisciplinary collaboration and mobilization of diverse expertise in addressing global societal challenges. It provides a flexible and responsive platform for academic institutions and diverse international actors to collectively address complex issues in digital governance with potential global reach and localized impact.

⁴Participating Centers are academic research centers whose agenda is primarily focused on Internet and society topics, while Affiliated Participants encompass other types of institutions with Internet and society-related open threads, carried out, e.g., as non-academic research centers, policy-support entities, or think tanks. See also <https://networkofcenters.net/centers>

3 THE NoC AND SCIENCE DIPLOMACY: INSIGHTS AND IMPACT

As noted at the outset, the NoC is not explicitly conceived as a science diplomacy effort. Nonetheless, a closer examination of the NoC in facilitating international dialogue, informing policy development, and supporting capacity building across different governance levels reveals commonalities with science diplomacy initiatives. Science diplomacy (SD) is a multifaceted concept that bridges science, international relations, and public policy (Krasnyak and Ruffini 2020; Lüder 2024). It has often been defined as the use of “scientific collaborations among nations to address common challenges and build international partnerships” (Fedoroff 2009). Over time, SD has evolved from traditional state-centered diplomacy into a more inclusive concept that incorporates non-state actors and institutions, reflecting the growing importance of science, technology, and innovation in global governance (Copeland 2016; Berkman 2019; Legrand and Stone 2018). As global challenges become increasingly complex, the role of SD in fostering multilateral and international action has become more significant, for example, by informing national policymakers when engaging and participating in global governance (Turekian et al. 2015).

The Role of Academic Networks in Science Diplomacy

It is broadly acknowledged in literature and practice that academic networks can play a crucial role in SD by acting as knowledge producers and facilitators of international cooperation and collaboration. They have the potential to foster trust, enhance mutual understanding, and provide a platform for dialogue independent of political pressures. During the Cold War, for instance, science diplomacy was instrumental in advancing non-proliferation and arms control efforts, leveraging science as a neutral ground for engagement (Copeland 2016). In today’s global policy environment, SD remains a vital channel for sustaining international peace and prosperity, though it now involves a broader range of actors and more intricate governance networks (Legrand and Stone 2018). Organizations and institutions practice SD with and without specific reference to the concept, including intergovernmental research organizations (e.g., European Organization for Nuclear Research [CERN]), international organizations (e.g., UNESCO), foundations (e.g., Geneva Science Diplomacy Anticipator [GESDA]), and non-governmental organizations (e.g., Scientists without Borders).

Despite the progress of science diplomacy and related academic initiatives, challenges remain in ensuring equitable outcomes and navigating divergent state interests (Turekian et al. 2015). The evolving role of non-Western nations in science diplomacy, including initiatives in Latin America that leverage scientific collaboration for local policy (Da Silva et al. 2021; Soler 2021), illustrates the changing landscape of global governance. However, there is a significant

gap in empirical research regarding the impact of these initiatives (Flink 2022). Most current models are rooted in the Global North, indicating the need for capacity building in other regions to develop tailored science diplomacy structures that address specific local contexts (Soler 2021).

The three widely applied SD dimensions of science in diplomacy, diplomacy for science, and science for diplomacy—with recognized limitations—provide a helpful framework to assess the contributions to and the role of the NoC as a “network of networks” in science diplomacy (The Royal Society 2010).

Science in Diplomacy: Policy Advisory and Knowledge Sharing

“Science in diplomacy” emphasizes the role of scientific knowledge in informing and shaping foreign policy decisions (Turekian et al. 2015). This dimension typically involves the translation of scientific research into actionable policy recommendations that address global challenges. Effective policymaking requires timely, relevant scientific input, supported by strong linkages between academic experts and policymakers (Turekian et al. 2015). Researchers increasingly act as “new diplomats,” bridging the gap between science and policy at both domestic and international levels (Legrand and Stone 2018). Academic networks like the NoC can become key facilitators in this context, as they establish information flows and institutional mechanisms for knowledge exchange as well as actively advancing scientific perspectives for policy debates at the science-policy-society nexus (Lüdert 2024).

The NoC fosters knowledge exchange and informs policymaking through initiatives like the 2015 *Multistakeholder as Governance Groups* global research project (BKC 2015). Facilitated by BKC, this initiative of academic institutions from around the world conducted research in parallel to analyze and synthesize 12 case studies on multistakeholder governance frameworks in a highly compressed timeframe (Gasser et al. 2015). The project aimed to support efforts aimed at enhancing the effectiveness and inclusivity of these multistakeholder governance frameworks in the digital age, with a specific focus on informing internationalization efforts of the Internet Corporation for Assigned Names and Numbers (ICANN) at the time. The project aimed to distill lessons from diverse governance models across contexts, emphasizing global perspectives and collaborative research, to offer evidence-based, actionable insights to policymakers and stakeholders in a timely manner. The research was situated within a broader context of ongoing developments in the Internet governance ecosystem, including discussions at the Internet Governance Forum and the NETmundial Initiative. The case of NoC’s work on the contested concept of multistakeholder groups was not only indicative of an initiative to inform global policy discussions on multi stakeholder governance (science in diplomacy) but also one that aimed to enable international collaboration and create a public-interest oriented platform for dialogue among diverse stakeholders, contributing to international science collaboration bottom-up (diplomacy for science).

Since its launch, the NoC and its participating Centers have acted in various configurations and contexts and on a broad range of topics in an advisory function and as a sounding board to inform policy and policymakers, contributing to global best practice sharing, and enhancing interoperability across norms, organizations, and processes. A recent example includes the collaboration between the Secretariat of the NoC, with TUM Think Tank and the German International Cooperation Society (GIZ) to support the government of Mauritania in its efforts to develop a National AI Strategy (Government of Mauritania 2024). The NoC Secretariat also crafted a Summary Report on Costa Rica's Draft AI Bill (No. 23.919), titled "Insights and Recommendations for Policy Makers in Latin America and the Caribbean" and published in July 2024, leveraging scientific knowledge of the NoC to provide inclusive AI governance guidance (Guio and Müller-Daubermann 2024). A broad variety of NoC-facilitated outputs, including policy briefs (such as the Regulatory Sandboxes for Achieving SDGs for the G20, Halim et al. 2024) or consultations (for instance, by providing assistance to the German Digital Council when assessing a draft of the German AI Strategy), illustrate the NoC's active role in shaping international policy through targeted advisory efforts.

Diplomacy for Science: Facilitating International Collaboration

"Diplomacy for science" focuses on leveraging diplomatic efforts and channels to promote international scientific collaboration. These initiatives can emerge from national diplomatic actors or grassroots efforts within research institutions (Turekian et al. 2015). This dimension underscores the importance of national and international institutional actors, as well as individual scientists and scientific communities in enabling cross-border research collaborations in addressing global issues.

The NoC exemplifies a bottom-up, community-led initiative that can foster cross-border research and collaboration (Lacerda et al. 2023). Such networks can contribute to overcoming barriers to cooperation, especially in politically sensitive areas, by facilitating the global exchange of scientific knowledge and supporting regional capacity building initiatives (Van Langenhove 2017). As demonstrated in the path of the NoC over the past decade, "diplomacy for science" efforts have the potential to enable activities in the other two dimensions of science diplomacy, by bringing together the interdisciplinary network of academic institutions and partner organizations.

Throughout the years, the NoC has advanced a hub model—consisting of regional hubs in Europe and Asia, with a potential hub in North America currently under consideration—to foster collaboration at the local and regional level. In 2015, for instance, the Digital Asia Hub⁵ was launched, focusing on three main areas: research, knowledge sharing, and capacity building. Incubated by the NoC together with a diverse group of academic, civil society, and private

⁵ Digital Asia Hub: <https://www.digitaliasiahub.org/>

sector partners, the Digital Asia Hub aims to provide a non-partisan, open, and collaborative platform for research, knowledge sharing, and capacity building related to Internet and Society issues with a focus on digital Asia. Its activities and research explore opportunities and challenges in digital technology and society in Asia, covering topics such as digital rights, governance and cyberlaw, innovation and digital trade, emerging technologies, the impact of mobile technology, and ICT for development. With both local and regional activities, the Hub aims to strengthen multistakeholder discourse and to contribute to the larger network of the NoC. Similarly, a European Hub was launched in 2017 by centers from the region, in an effort to support researchers and strengthen relationships between scholars in the region. These examples of regional efforts have created spaces for scientific and diplomatic interaction among different stakeholders and disciplines, contributing both to regional capacity building and exchange with the global network.

In addition, participating Centers of the NoC have pioneered clinical models that serve as collaborative protocols and frameworks for innovative methodologies that bridge the spheres of academic research and on-the-ground capacity building. A lead example is the formation of the AI Governance Clinic (AIGC) (now AI Governance Center) launched in 2022 in Thailand. Co-conceptualized and incubated by the NoC, under the lead of the Digital Asia Hub Thailand and TUM Think Tank and hosted by the Electronic Transactions Development Agency (ETDA) of Thailand, it fosters a diverse knowledge network of local and international experts to build AI governance capacity (Gasser and Albrecht 2024). AIGC builds knowledge networks by bringing together local experts across sectors through a fellowship program, supported by an International Policy Advisory Panel. Furthermore, it engages in the development of actionable guidelines and toolkits, like the “AI Governance Guidelines for Executives,” building upon Thailand’s national policies and principles, as well as engaging in educational initiatives, to encourage lifelong learning and provide practical frameworks for AI readiness and risk management.

These initiatives illustrate NoC’s capacity to transcend traditional roadblocks to cooperation by facilitating capacity building and supporting regional engagement in novel models of private-public and local-international partnerships. This approach does not come without challenges, as the decentralized nature of NoC makes it difficult to sustain consistent and equitable collaboration across regions with varying capacities. Addressing these challenges is a focus of NoC’s latest roadmap for 2024–2026, which aims to enhance internal cohesion and embrace collaborative potential across the full network (Network of Centers 2024).

Science for Diplomacy: A Trusted Ground for Collaboration and Impact

“Science for diplomacy” utilizes science as a mechanism to improve international relations, embodying values like evidence-based decision-making and

scientific freedom (Turekian et al. 2015). This dimension is particularly relevant in contexts where scientific cooperation can serve as a common ground for dialogue, or even conflict resolution. “Science for diplomacy” often leverages the soft power potential of scientific collaboration through agreements, joint research centers, or international conferences. Networks like the NoC can play a central role in such endeavors, for instance, by facilitating knowledge sharing, and best practices or the formation of interdisciplinary and international communities of practice, all of which might contribute to more effective and more interoperable global policies.

The *Ethics of Digitalization* project, led by the Alexander von Humboldt Institute for Internet and Society within the NoC and under the patronage of the German President, is a case in point. The NoC initiative examined the ethical implications of digital technologies and AI (BKC 2024). This project built on a 2019 visit of the German President Frank-Walter Steinmeier to Harvard University, where he described efforts to promote a global dialogue about “our responsibility for the future and how digital transformation will (...) reshape industry, government, and society” (BKC 2019). Invited to accompany and facilitate these diplomatic efforts, the Ethics of Digitalization project drew on the NoC’s interdisciplinary, global, and diverse expertise, to collaborate on developing ethical frameworks and policy recommendations. The project illustrates how academic initiatives like the NoC can activate a broader network of institutions and partner organizations, resulting in a series of co-designed and co-hosted research sprints, interdisciplinary clinics, workshops, and other activities in Europe, the USA, and Asia to bolster a global diplomatic effort.

Shifting topic and geographic context, the NoC’s *Online Intermediaries Project*—which can be considered both a “science in diplomacy” and a “science for diplomacy” initiative—provides an example of NoC activities aiming to improve international relations, inform digital policies across geographies, and contribute to a level playing field for the global digital economy. Coordinated by the NoC and facilitated by the BKC, this research project examined the evolving landscape of online intermediary governance, particularly focusing on intermediary liability frameworks, at the intersection of law, technology, norms, and markets. Based on a series of case studies, the project resulted in a synthesis paper, summarizing the findings of in-depth explorations of online intermediary liability frameworks in Brazil, the European Union, India, South Korea, the USA, Thailand, Turkey, and Vietnam (Gasser and Schulz 2015). Committed to global perspectives and rigorous academic standards, the study provided lessons learned and actionable insights for policymakers while contributing to a broader academic strategy for understanding and addressing digital governance. The findings were presented to members of the Korean National Assembly in a hearing on online intermediary liability.

NoC fosters global understanding by centering its work on four pillars: diversity, openness, independence, and evidence-based research. This commitment allows the network to connect diverse disciplines and cultures effectively. In this context, the latest NoC Progress Report (2024) highlights key elements

for sustaining engagement and impactful global collaboration, marked by strengthened regional hubs in Africa, Latin America, and Asia, expanded collaborative work on AI governance and regulatory experimentation, and deeper engagement with United Nations institutions on AI governance, digital public infrastructure, and the ethical use of emerging technologies. The main objective has been to create greater opportunities for shared learning and interoperability (Network of Centers Secretariat 2025). This positions the NoC as a trusted actor in advancing technology and society discourse and capacity building amid geopolitical fragmentation.

Looking ahead, the Network will aim to consolidate regional hubs, advance comparative research on AI governance and regulatory experimentation, and develop new structured foresight initiatives, such as a Generative Futures Commission, which will assess emerging technological trajectories and their societal implications to inform evidence-based, public-interest-oriented governance. Collaborative reflection (Kamali and Javahery 2025) will be a central element of this next phase, reinforcing the NoC's role in sustaining dialogue, trust, and scientific diplomacy across regions.

4 CONCLUSION

The NoC illustrates the potential of academic networks to contribute to science diplomacy by addressing complex global challenges in the digital and now AI age. Its evolution and activities showcase how interdisciplinary collaboration can advance knowledge production, inform policy, and foster mutual understanding across traditional boundaries and diverse contexts. By aligning its mission with principles of openness, collaboration, and diversity, the NoC has established itself as a platform for academic and policy-driven dialogue. Its initiatives, such as the Ethics of Digitalization project and regional hubs like the Digital Asia Hub, demonstrate how academic networks can operate as facilitators of cross-border cooperation and policy harmonization, contributing to both regional and global capacity building.

The NoC case study also highlights the promise of exploring new avenues how academic networks can operate at scale and over time as well as experimentation with new forms of collaboration and engagement despite growing incentives toward fragmentation. The NoC's commitment to decentralized and networked governance has allowed it to adapt to emerging challenges while maintaining independence and embracing the diversity of its participants and partners. However, the NoC experience also highlights challenges inherent in such a model, particularly in enabling equitable participation and sustaining engagement across regions with varying capacities.

Addressing these challenges requires a careful balance between fostering localized efforts and maintaining a coherent global strategy. In this regard, regional hubs have proven helpful, and the existence of an independent Secretariat to coordinate efforts can be a significant asset. The network's roadmap for 2024–2026 and the Progress Reports (2024, 2025) illustrate a

commitment to enhancing internal cohesion and maximizing its impact on science diplomacy, positioning the NoC to lead the way in creating sustainable frameworks for interdisciplinary collaboration.

In conclusion, the NoC as a case study offers valuable insights when envisioning academic networks as mechanisms for science diplomacy in an era of technological disruption and geopolitical rivalry. It underscores the importance of integrating diverse perspectives and offering platforms with appropriate guardrails for dialogue to address global challenges. In addition to a variety of national and regional governance institutions and networks, international organizations such as the International Telecommunications Union (ITU) and UNICEF have increasingly engaged with the NoC as a trusted platform for convening global discussions and identifying emerging issues in the governance of technology in a particularly challenging context for these organizations.

As digital and AI governance continue to evolve, the NoC provides inspiration when considering ways in which academic institutions can collaborate across boundaries to promote evidence-based decision-making, build trust, and contribute to more inclusive and equitable global governance. The lessons drawn from the NoC and its initiatives might inspire similar efforts in different domains and contexts, highlighting the transformative potential of interdisciplinary academic networks in shaping the future of science diplomacy and the innovative formation and operation of such networks.

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American Science and Technology for Development: Where We Have Been, Where We Are Now, and Where We Need to Go

Elmer William Colglazier

I INTRODUCTION

The progress achieved over 50 years for advancing the science and technology capacity of emerging countries has contributed to their prosperity, security, and competitiveness. Important initiatives in science and technology aiding development, undertaken by collaborations of wealthy countries, poor countries, and international institutions, have made a difference. Many developing countries today are able partners in international scientific and technological cooperation with a rapidly growing percentage of scientific authors worldwide coming from these nations (de Brito Cruz 2025).

Yet much remains to be accomplished. The accelerating scientific and technological revolution has produced an amazing array of new opportunities for humanity. Emerging technologies such as artificial intelligence, quantum, synthetic biology, blockchain, robotics, and big data have an enormous potential for benefiting every country, but they are also producing new threats and competition among countries. In addition to increasing climate change, uncontrolled migration, and widespread poverty, the 2020s unleashed more setbacks with the COVID-19 pandemic, increased geopolitical conflict, two violent wars, and unexpected trade wars.

The 2024 US election produced a surprising new hurdle for third world development with the US government withdrawing from using its science and

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technology capabilities and resources to help build science and technology capacity in emerging countries. The world is indeed in an era of technological and political disruption. Yet the need for increasing international cooperation and harnessing new pathways for progress created by advances in science and technology (S&T) is essential if we are to achieve a brighter future for the developed and developing world.

2 A PERSONAL PERSPECTIVE ON SCIENCE AND TECHNOLOGY FOR DEVELOPMENT IN EMERGING COUNTRIES

This chapter is an American perspective over five decades on “where we have been, where we are now, and where we need to go” on S&T for development. My interest started in 1976 when I took a leave of absence from being a research physicist to serve as an American Association for the Advancement of Science (AAAS) S&T Policy Fellow on the Congressional staff of Representative George E. Brown. He was a great champion of using American science and technology for aiding emerging countries through scientific collaboration. I soon left an assistant professorship and physics research to work for 5 years at the newly created Center for Science and International Affairs at Harvard University and the Program on Science, Technology, and Humanism at the Aspen Institute. There I devoted considerable time to the effort to create a new US government agency focused on the role of science and technology for development.

In March of 1978, President Carter proposed the creation of such an agency that would emphasize cooperation between the United States and the Third World. It would foster research, strengthen indigenous capabilities, and facilitate scientific and technological cooperation. This new agency would have much in common with the International Development Research Center (IDRC) in Canada, including, like IDRC, sponsoring research in developing countries led by nationals in those countries. The Institute for Scientific and Technological Cooperation (ISTC) became the name of the proposed government agency.

With the Institute for Scientific and Technological Cooperation and the existing US Agency for International Development (USAID), the United States would have two development agencies like Canada. The Institute for Scientific and Technological Cooperation would support training and research on key development and global problems including at regional institutions such as the Agricultural Research Centers. It would provide mechanisms for collaborative projects in science and technology between American and foreign institutions, including participation by middle-tier developing countries. Harvard Professor Paul Doty and I helped organize a conference at the Aspen Institute in 1978 to discuss a blueprint for the Institute for Scientific and Technological Cooperation, which included its planners, congressional staff, members of the US scientific and technical community, and scientists from developing nations (Colglazier and Doty 1980).

In 1979, the Institute for Scientific and Technological Cooperation was authorized by Congress. However, funding was not appropriated due to opposition in the Senate. Some of the opposition came from those who felt two agencies would be duplicative and divert resources from addressing basic human needs of the poor. Some of the negative voices even came from USAID. There was also concern about aiding other countries in industrialization. However, the 1980 House-Senate Appropriations Conference Committee did approve \$12 million to USAID for programs similar to those envisioned in the Institute for Scientific and Technological Cooperation. Throughout the 1980s, increased funding at USAID was directed toward science and technology for development. The US National Academy of Sciences, Engineering, and Medicine was entrusted to manage a large number of programs through its Board on Science and Technology for International Development (BOSTID) within its Office of International Affairs (OIA).

OIA encompassed committees and programs covering all aspects of international issues with the mandate for marshaling scientific expertise and knowledge to benefit people and societies everywhere. Studies, workshops, and international scientific engagements overseen by OIA were carried out by the Committee on Scholarly Communication with China (with an office in Beijing), the Committee on Japan, the Committee on International Organizations and Programs, the Committee on Human Rights, the Office of Central Europe and Eurasia, the Committee on International Security and Arms Control, and the Board on Science and Technology for International Development. OIA also staffed dialogues between the National Academy of Sciences leadership and the leadership of other scientific academies, including the Royal Society, the Soviet/Russian Academy of Sciences, and the Chinese Academy of Sciences.

As OIA's largest unit, the Board on Science and Technology for International Development (BOSTID) focused on international scientific engagement with lower- and middle-income countries. The purpose was to build their scientific capabilities and to help them improve the lives and livelihoods. Among the programs was a large effort funded by USAID to select through peer review research projects addressing development topics carried out by scientists in these countries. The wide variety of BOSTID studies is illustrated by this selection from the 1980s and 1990s:

Lost Crops of Africa (1996)

Sustainable Agriculture in the Humid Tropics (1993)

Vetiver Grass: A Thin Green Line Against Erosion (1993)

Conserving Biodiversity: A Research Agenda for Development Agencies (1992)

Micro-livestock: Little-Known Small Animals with a Promising Future (1991)

Toward Sustainability: Soil and Water Research Priorities for Developing Countries (1991)

Saline Agriculture: Salt-Tolerant Plants for Developing Countries (1990)

Lost Crops of the Incas (1989)

U.S. Policy for the 1990s: Science and Technology for Sustainable Development (1989)
 Science and Technology Information Services and Systems in Africa (1989)
 Fisheries Technologies for Developing Countries (1988)
 U.S. Capacity to Address Tropical Infectious Disease Problems (1987)
 Workshop on Biotechnology in Agriculture (1986)
 Opportunities in Marine Science and Technology for Developing Countries (1985)
 Workshop on Thai-U.S. Science and Technology Collaboration (1984)
 Amaranth: Modern Prospects for an Ancient Crop (1984)
 Crocodiles as a Resource for the Tropics (1983)
 Panel Discussions on Science and Technology Planning and Forecasting for Indonesia: Special Emphasis on Manpower Development (1983)¹

The Board on Science and Technology for International Development (BOSTID) had become a major resource for programs, studies, dialogues, and engagement in science and technology for development and an important legacy of its first director, Victor Rabinowitch, showing how S&T can be marshaled to advance prosperity, security, and peace throughout the world. I was fortunate to inherit this legacy at the National Academies when I became executive director of the Office of International Affairs in 1991.

In 1991, the new Administrator of USAID, Brian Atwood, wrote an op-ed during the drafting of the Clinton administration's report on foreign assistance reform. He emphasized four strategic objectives, the environment, population and health, economic growth, and democracy, and stated: "Our nation must reassert its leadership in the field of sustainable development" (Atwood 1993). While he did not mention the role of science and technology, the effort begun in the 1980s at USAID continued into the 1990s. The US National Academies expanded its effort using science and technology and international collaboration to benefit not only the United States but countries everywhere.

3 JOINT PROJECTS AND STUDIES BY THE NATIONAL ACADEMIES RELEVANT FOR DEVELOPING COUNTRIES

The Office of International Affairs strategic plan in the 1990s emphasized joint projects and studies with developing countries, addressing key issues of importance to both countries. The goal was to strengthen the ability of foreign partners to be influential, independent advisers to their governments on public policy issues and decisions where inputs from science and technology are needed. The model was that of what the US National Academies are mandated to do in advising the American government and public. The hope was that

¹ All of the reports of the National Academies mentioned in this chapter are accessible in full text for free at nap.edu

stronger science advisory ecosystems in other countries would help lead to wiser decisions. The domestic science and technology community in a country was more likely to influence its government than advice from foreigners. This approach may seem idealistic for the hard realities of government decision-making in much of the world, but it has influenced many of the international activities of the US National Academies ever since.

One of the largest efforts in the 1990s was carrying out a project for the Government of Indonesia funded by a World Bank loan. The Office of International Affairs had several staff and an office in Jakarta. The focus was strengthening indigenous S&T institutions, including universities and national labs, to be more effective in working with and contributing to the productive sector of the Indonesian economy. The purpose was to assist the private sector including with applications of high technology. The project had an objective to improve peer review in awarding research projects and advancing scientific personnel. It also included the longer-term goal of creating a science funding institution in Indonesia like the US National Science Foundation. The Indonesians did benefit from the joint effort, and a cohort of bright young Indonesians were trained. The Americans learned of the challenges of strengthening scientific institutions in developing countries.

The National Academies carried out many studies addressing issues relevant to developing countries during the 1990s and early 2000s. Some were carried out jointly with scientific institutions in specific countries, including with China and in the Middle East. Among the studies and activities carried out during this period were:

- Marshaling Technology for Development (1995)
- Meeting the Challenges of Megacities in the Developing World (1996)
- America's Vital Interest in Global Health (1997)
- Control of Cardiovascular Diseases in Developing Countries (1998)
- The Pervasive Role of Science, Technology, and Health in Foreign Policy (1999)
- Our Common Journey: A Transition Toward Sustainability (1999)
- Water for the Future: The West Bank and Gaza, Israel, and Jordan (1999)
- Cooperation in the Energy Futures of China and the United States (2000)
- Transgenic Plants and World Agriculture (2000)
- The Future of Personal Transport in China (2001)
- Growing Populations, Changing Landscapes: Studies from India, China, and the United States (2001)
- Personal Cars and China (2003)
- Cities Transformed: Demographic Change and Its Implications in the Developing World (2003)
- Urbanization, Energy, Air Pollution in China: The Challenges Ahead (2004)
- Learning from SARS: Preparing for the Next Disease Outbreak (2004)
- The Role of Science in Solving the Earth's Emerging Water Problems (2005)
- Lost Crops of Africa: Vegetables (2006)

The studies related to China and the Middle East were in collaboration with scientific academies and other institutions in those countries. During this period, National Academy of Sciences president Bruce Alberts chaired a committee for the World Bank reviewing the CGIAR agricultural research institutes and making recommendations on how to strengthen them.

4 INTERACADEMY PANEL, INTERACADEMY COUNCIL, AND THE ASADI PROGRAM

Representatives of national academies from around the world met in New Delhi in October 1993 in a Science Summit on World Population. The outcome was a statement signed by 58 academies aimed at the UN International Conference on Population and Development in 1994 (National Academy of Sciences et al. 1993). The recommendations addressed (i) key determinants of population growth; (ii) resource consumption, the environment, and quality of life on a finite earth; (iii) human reproductive health; (iv) sustainability of the natural world as everyone's responsibility; (v) what S&T can do to enhance the human prospect; and (vi) the need for action now.

The New Delhi conference stimulated the creation of the InterAcademy Panel in 1993. Its focus was on building capacity, capabilities, and influence of science academies across the world. A particular emphasis was assisting science academies in becoming important advisers to their governments and public on policy issues where science is relevant. In 2000, the InterAcademy Medical Panel was created with a similar purpose for medical academies. In 2003, the InterAcademy Council was formed to undertake studies at the global level for the UN and other international decision-makers. It operated under a board of science academy leaders from 15 countries and under procedures similar to those of the US National Academies. More recently, all three organizations were united as the InterAcademy Partnership (IAP), with the InterAcademy Panel, the InterAcademy Medical Panel, and the InterAcademy Council becoming IAP Science, IAP Health, and IAP Policy, respectively.

The IAP currently has 140 national academy members, 4 global and regional academies, and 4 regional networks. The significance of IAP's work is illustrated by its studies such as:

- (i) Climate Change Assessments: Review of the Processes & Procedures of the IPCC
- (ii) Responsible Conduct in the Global Research Enterprise
- (iii) Supporting the Sustainable Development Goals: A Guide for Merit-Based Academies
- (iv) Opportunities for Future Research and Innovation on Food and Nutrition Security and Agriculture: The InterAcademy Partnership's Global Perspective (with separate reports on Africa, Asia, Americas, and Europe)
- (v) Harnessing Science, Engineering and Medicine to Address Africa's Challenges: The Role of African National Academies

- (vi) Improving Scientific Input to Global Policymaking with a Focus on the UN Sustainable Development Goals
- (vii) Decarbonization of Transport: Options and Challenges

The study on the IPCC requested by the UN Secretary General helped strengthen IPCC processes and procedures and restore international confidence in this important institution.

Statements endorsed by the IAP academies include:

Urban Development
 Transition to Sustainability
 Mother and Child Health
 Calling for a Ban on Reproductive Cloning
 Science Education
 Science and the Media
 Scientific Capacity Building
 UN Millennium Development Goals
 Biosecurity
 Ocean Acidification
 Tropical Forests and Climate Change
 Population and Consumption
 Action to Strengthen Health Research Capacity in Low and Middle Income Countries
 Antimicrobial Resistance: A Call to Action
 Realizing Global Potential in Synthetic Biology: Scientific Opportunities and Good Governance
 Reproducibility of Biomedical Research: A Call for Action
 Science and Technology for Disaster Risk Reduction

An effort for strengthening African science academies as public health advisers to African governments was the African Science Academy Development Initiative (ASADI) (National Academies [n.d.](#)) This network created in 2004 and funded for 10 years by the Gates Foundation produced studies on health issues of importance to Africa. All together, these multiple efforts of science academies have helped strengthen the role of science advice to governments and the public in developing and developed countries.

5 OUR COMMON JOURNEY: A TRANSITION TOWARD SUSTAINABILITY

Following the United National Conference on Environment and Development in 1992, known as the Earth Summit, the focus on sustainability issues increased significantly, including the role of science and technology. With the support of the George and Cynthia Mitchell Foundation, the National Academies produced the report *Our Common Journey: A Transition Toward Sustainability*

(1999). The title echoes the famous Brundtland Commission report of the previous decade, *Our Common Future*. There is a line in the 1999 report that is especially significant, emphasizing the journey that is needed. It emphasizes creation of a partnership between the scientific community and society to engender a journey of learning and doing, adaptive management, and social learning, in addressing global goals. As the study stated, “Any successful quest for sustainability will be a collective, uncertain, and adaptive endeavor in which society’s discovering of where it wants to go is intertwined with how it might get there.” The study also reinforced using knowledge “intelligently in setting goals, providing needed indicators and incentives, capturing and diffusing innovation, carefully examining alternatives, establishing effective institutions, and, more generally, encouraging good decisions and taking appropriate actions” (National Research Council 1999). This report had an influence when the UN created a mandate in 2015 to strengthen the science-policy interface as part of its 2030 Agenda for sustainable development approved by high-, middle-, and low-income countries.

6 PEPFAR, USAID GLOBAL DEVELOPMENT LAB, AAAS SCIENCE AND TECHNOLOGY FELLOWS, AND JEFFERSON SCIENCE FELLOWS

The President’s Emergency Plan for AIDS Relief (PEPFAR) was launched by President George W. Bush in 2003. It was an unprecedented effort of over \$80 billion invested in HIV/AIDS treatment, prevention, and research with special focus on Sub-Saharan Africa. The program’s creation was greatly influenced by President Bush’s visit to Uganda in 2003. Initiating PEPFAR is well described in Ambassador Jimmy Kolker’s article, “A Diplomat’s Perspective on Using Science and Evidence in Implementing PEPFAR” (Kolker 2018).

The USAID Global Development Lab was created in 2014 to focus on science, technology, and innovation (STI) for development. In many ways, it is the incarnation of the Institute for Scientific and Technological Cooperation (ISTC) idea proposed four decades earlier. Its purpose was to produce breakthrough development advances that can be scaled to bring benefits to many people. Its partnerships with foundations, private companies, and foreign institutions leveraged more than \$16 billion of non-USG funds. It sponsored Grand Challenges, breakthrough awards, funding to support foreign scientists collaborating with US scientists, entrepreneur accelerators, and university centers among its many creative programs.

The AAAS Science and Technology Policy Fellowship Program, created in 1972, now places more than 250 fellows each year serving in the agencies of the US government and Congress, including the State Department and USAID. After their 2-year fellowship experience, many fellows have become civil servants in the State Department, greatly increasing the number of professionals trained in S&T. The Global Development Lab expanded the number of

fellows at USAID, including a third year for select fellows to work in USAID overseas offices in developing countries.

The Jefferson Science Fellows program was created in 2003 for tenured science and engineering faculty at American universities to spend a year working on policy or international development in offices at the State Department and USAID. Over 170 fellows have served to date, and they have made significant contributions to America's foreign policy and development programs.

7 STATE DEPARTMENT AND THE UN: SCIENCE DIPLOMACY, STAS, MDGs, SDGs, TFM, AND CRDF GLOBAL

The position of Science and Technology Adviser to the Secretary of State (STAS) was created in 2000 based on a recommendation of the 1999 National Academies report *The Pervasive Role of Science, Technology, and Health in Foreign Policy: Imperatives for the Department of State*. With advisors each serving up to three years, the Science and Technology Adviser to the Secretary of State office has focused on many aspects of science diplomacy by engaging with many countries around the world on science, technology, and innovation and science advice to governments. Science diplomacy has been an important asset for US diplomacy.

The eight UN Millennium Goals (MDGs) were created in 2000 to focus for 15 years on the poorest countries. The ambitious goals with targets and indicators were to eradicate extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria, and other diseases; ensure environmental sustainability; and achieve a global partnership for development. Progress was uneven among countries, but some countries did well. Major reductions in the number of people living in extreme poverty were achieved.

The 17 Sustainable Development Goals (SDGs), covering social, economic, and environmental goals with targets and indicators applying to all countries, were approved in 2015 as the key element of the UN 2030 Agenda. The Technology Facilitation Mechanism (TFM) was created to strengthen the "science-policy" interface for harnessing science, technology, and innovation for achieving the SDGs. The Technology Facilitation Mechanism included an annual Multi-Stakeholder STI Forum at the UN each year, an InterAgency Task Team (IATT) consisting of a representative from each of more than forty UN agencies and international organizations, and the 10-Member Group consisting of non-governmental experts to advise on science, technology, and innovation for making progress on the SDGs. Many developing and developed countries have been active participants in the activities of the Technology Facilitation Mechanism.

CRDF Global was created 25 years ago under its founding name, US Civilian Research and Development Foundation for the Independent States of

the Former Soviet Union (CRDF Global [n.d.](#)). The initial mandate was to “stop the brain drain of the region’s scientists and engineers, prevent the proliferation of weapons technologies, and create mutually beneficial economic and development opportunities between the U.S. and Post-Soviet states.” Later, the name was changed to CRDF Global as the geographic reach expanded to include the Baltics, Middle East, Africa, Asia, and Latin America. Its programs expanded to include “entrepreneurship, international exchanges, global health, and higher education institution building” among others. Much of the work has been conducted with funding from the US State Department and other federal agencies. Among the elected officials instrumental in the creation of CRDF Global was Representative George E. Brown. For many years, CRDF Global presented annually the George E. Brown award for international scientific cooperation.

8 IIASA, ISC, INGSA, AND THE GLOBAL SOLUTIONS SUMMIT

International S&T non-governmental organizations that are networks have become powerful forces for addressing national and global challenges including sustainability and S&T for development. The International Institute for Applied Systems Analysis (IIASA), which celebrated its 50th birthday in 2022, was created as an initiative of the United States and the Soviet Union to enable their scientists to work together to apply systems analysis to problems of common interest. IIASA now has many participating developed and developing countries represented by national member organizations and carries out work on some of the most important challenges facing the world. Among influential initiatives launched by IIASA is The World in 2050 project, which presented three reports to the UN High Level Political Forum beginning in 2018. Among the insightful analysis is an exploration of big transformations required for achieving sustainability. The key areas are:

1. Education, gender, and inequality
2. Health, well-being, and demography
3. Energy decarbonization and sustainable industry
4. Sustainable food, land, water and oceans
5. Sustainable cities and communities
6. Digital revolution for sustainable development (International Institute for Applied Systems Analysis [2023](#))

The International Science Council (ISC) united the International Council for Science and the Social Sciences Research Council in 2018. It is an international non-governmental association with 40 international scientific unions and associations and over 140 national and regional scientific institutions (International Science Council [n.d.](#)) The Council’s strategic plan for 2019–2021 encompassed science for policy, policy for science, and scientific freedom and

responsibility. Aspiring to be the international voice for science, the International Science Council conducts many meetings and produces significant reports addressing a wide variety of issues where science input is needed, including sustainability issues and development issues. ISC is co-convenor of the UN Major Group for Science and Technology.

The International Network for Government Science Advice (INGSA) was created in 2014. The list of activities and programs undertaken by INGSA over the past 5 years is quite extraordinary:

- A network of over 5500 members from developed and emerging countries throughout the world
- Capacity-building workshops in more than fifteen countries
- Training more than 1700 individuals including policy-makers, senior scientists, and early-career scientists
- Dialogues and focused meetings in a range of countries involving more than 1000 participants and jointly organized with local institutions and often with international institutions
- Advisory services provided with a range of countries
- Creation of an open platform for information exchanges
- A vibrant social media presence
- Development of a catalog of case studies
- Sponsoring its own international and regional conferences
- Financial support raised from governments and philanthropies
- Partnerships with international and national organizations
- Becoming an autonomous entity of the International Science Council
- Supporting research associate grants and fellowships
- A science diplomacy unit that works with the Foreign Ministers Advice Network
- Recipient of science diplomacy awards by the American Association for the Advancement of Science and the Science Forum South Africa
- Ongoing work and reports on key issues such as response to the COVID pandemic; the role of science, technology, and innovation for achieving the Sustainable Development Goals; societal resilience; the digital future; and assisting the Global South (International Network for Governmental Science Advice [n.d.](#))

The Global Solutions Summit was initiated in 2014, and a second Forum was held at the Clinton Library in 2016. In 2018 and 2019, Forums were held at the UN prior to each year's STI Forum. The focus of the Global Solutions Summit is technology deployment for the SDGs. In answering why deployment is so important, the Global Solutions Summit answers:

Harnessing STI for the SDGs starts with the work of scientists and engineers who develop high-performance, low-cost technological solutions for the SDGs. But this is only the first step on the long road from the lab to the SDG. The

indispensable next step entails transforming these scientific discoveries into affordable products and services and getting them into the hands of the hundreds of millions of people in tens of thousands of urban and rural communities in dozens of countries. (Global Solutions Summit [2023](#))

9 SCIENCE, TECHNOLOGY, AND INNOVATION FOR SDGs ROADMAPS

An innovative aspect of the Technology Facilitation Mechanism is the InterAgency Task Team working groups to focus on specific issues and initiatives. One of the most promising has been the working group on “STI for SDGs roadmaps.” A pilot program has been underway where five countries—aided by several UN agencies, the Government of Japan, the World Bank—are preparing their science, technology, and innovation for SDGs roadmaps.

The STI for SDGs roadmap is an action plan continuously updated and improved with input from the science, technology, and innovation community and others on what is and is not working. The roadmap is the common part of three other plans: the country’s national development plan, its STI capacity building plan, and its plan for achieving the SDGs. The intent is to engage not only prime ministers, finance ministers, S&T, and other ministers but also to engage all stakeholders in society in preparing the roadmap. The InterAgency Task Team working group has developed an informative guidebook for preparing roadmaps ([2021](#)).

Six pilot countries—India, Kenya, Ethiopia, Ghana, Serbia, and Ukraine—were the pilot countries chosen to begin preparing their roadmaps with some funding and assistance from developed countries and international organizations. All have made progress, although the war in Ukraine and the civil conflict in Ethiopia have complicated their plans. The European Union recently helped six Sub-Saharan countries begin preparing roadmaps with a report on their progress and methodology published in 2025 (Sarcina et al. [2025](#)). Other countries from the South are watching the progress and may decide to join the effort to prepare their own plans. The roadmap concept is also applicable to all levels of government, from local to global, as well as non-governmental institutions and private companies. All institutions could benefit from preparing their own roadmaps for how to contribute toward harnessing science, technology, and innovation to help achieve local, national, and global goals.

10 THE CRISES AND SETBACKS OF THE 2020s

The COVID-19 SARS-COV-2 pandemic that began in 2020 was a searing experience with many deaths worldwide. It was a challenging time for the science, technology, and public health communities. Even with the failures at the national and global level coping with the pandemic, the global scientific community around the world did respond with unprecedented scientific collaboration and sharing of information. S&T advances produced in record time new

mRNA vaccines that provided the ultimate solution for defeating this pandemic. However, the aftermath also resulted in increased political dysfunction, a lessened trust in advice from the scientific community, and a drop in the willingness of developed countries to provide critical aid to poor countries.

The current geopolitical and global challenges for national security and international relations only continued to increase in the 2020s. By the end of 2024, the list of problems became long: competition and conflict between the United States and China; the Russian invasion of Ukraine; the alliance among Russia, China, Iran, and North Korea; lapsed nuclear arms control agreements; the Middle East War; economic stresses with high inflation and increased debt loads; and de-globalization and fraying supply chains. Additional stresses emerged, including (i) autocratic leaders and increased political polarization, (ii) some countries losing faith in democracy, (iii) emerging countries faced with navigating a multipolar world, (iv) uncontrolled migration, (v) a lack of progress on the 17 Sustainable Development Goals, (vi) climate change coming faster, (v) loss of faith in science and technology making the world better, and (vi) emerging technology threatens overwhelming societies ability to regulate.

Like many observers, including myself, I did not foresee the dramatic and devastating blows in 2025 by the Trump administration against the US national science and technology enterprise. The bipartisan political support in the United States for ensuring the well-being of America's S&T—seen as essential for security, economic competitiveness, health, and well-being—lasted for 80 years, but it has now ended. Young and senior scientists alike are losing their jobs, funding is being cut for research, fewer foreign students and scientists are coming to the United States, premier government agencies dealing with S&T and leading research universities are being harmed, and the pipeline for the next generation of researchers in S&T is at risk.

The administration has drastically curtailed policies, actions, and research funding addressing climate change, public health, and environmental protection. The actions were particularly devastating for US efforts aimed at helping emerging countries. The US Agency for International Development was effectively eliminated, except for a few programs transferred to the State Department. The American effort over four decades to use science and technology to aid development of emerging countries has finished for now. Renewing it may take a generation.

Yet the national interest of the United States, as well as that of other developed countries, is to make all countries of the world more resilient, prosperous, secure, peaceful, sustainable, and democratic. The strategy for accelerating S&T for development embraced by the Board on Science and Technology for International Development in the 1980s is as vital today as it was then. That strategy encompasses helping middle- and low-income countries to (i) build their science, technology, and innovation ecosystems; (ii) enhance their science advisory ecosystems for providing scientific input into societal decision-making; (iii) enable multilateral cooperation and international scientific cooperation to

make progress on each country's social, economic, and environmental goals; and (iv) work together to make progress on the global goals that will protect and sustain humanity and the planet.

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Agents of Disruption? On the Role of Private Actors as Drivers of Innovation and the Limits of Government Steering Mechanisms for Science and Technology

Christian E. Rieck 

1 INTRODUCTION

The question that triggered this short exploration on managed disruption stems from a general dissatisfaction with the scale and scope of state-led innovation, i.e., with the steering mechanisms deployed by ministries of science and technology and state-funded science administrations: *How can a ministry of research and technology foster disruption in science and technology through funding and regulation, the two most common instruments at its disposal? Who are the real agents of technological disruption? How can disruptive innovation serve the public good? Under which conditions can the state play this role, or can it always and only be filled by private actors?*

Clearly, private sector behemoths such as Google have pockets deep enough to research and develop moonshot ideas with global disruptive potential, the stated objective of its own “moonshot factory” that has incubated and spun out projects ranging from neural networks to smart contact lenses to balloon-deployed Internet to self-driving taxis (X 2025). But the original moonshot was undertaken in 1969 by NASA, a government agency—and it is CERN, an international big science organization, which runs the world’s most powerful particle accelerator that has uncovered the Higgs Boson, the now famous “god particle,” in 2012 and continues to push the boundaries of the field to this day

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(CERN 2025). NASA's Apollo Program has led to a series of innovations with military and civilian applications, while CERN makes all of its results available to the scientific community and, thus, the public.

The hypothesis that arises from this cursory glance at the history of innovation is that there might be complementarities between state-led and private actor-led science and technology (S&T) that would be useful to combine and exploit in the interest to maximize output and impact. If so, *which conditions have to be met for such a public-private (or private-public) endeavor to be successful? How can financially potent private actors be integrated into collaborative research efforts to solve deep problems—at least in those areas where they are research dominant?*

2 THE CREATION-TRANSLATION-IMPLEMENTATION GAP

These questions are highly relevant because, in countries around the world, a curious “creation-translation-implementation gap” arises: Despite ambitious state funding for research and development (R&D), too often, the generated results do not adequately make their way into national and international *policies* (science in diplomacy), mainly because national or international *politics* gets in the way (Benner 2021; Gottstein and Matz 2007).

One of the most glaring examples today seems to be the gap between climate science, climate policies, and climate diplomacy where scientific results—from national researchers as well as from the Intergovernmental Panel on Climate Change IPCC that represents the global consensus on climate science—are politicized or, in some cases, repudiated as unreliable. Also, as the logic of political decision-making requires actionable indicators and goals to organize the majorities necessary to design and implement policies, this often leads to an overreliance on isolated targets, for global warming (“1.5 degrees”), say, or for greenhouse emissions reductions (“55 percent less than 1990” for the EU). Such targets do not necessarily adequately reflect the complexity of the policy field nor of the scientific discourse in question (SAPEA 2019, 79–86). Once state bureaucracies and state leaders take the helm in international negotiation settings, the scientific actors usually become mere observers—no matter the quality of the negotiated results (diplomacy against science).

This gap is clearly visible in domestic contexts where, say, climate policies clash with economic imperatives. But it is compounded in international settings, be it on the input side in the form of a bias against actors that might have the necessary innovation potential but are left out of innovation making because of national science political or bureaucratic reasons and/or on the output side in the form of a suboptimal production of (disruptive) innovation or (global) public goods, leaving all of us worse off. Yet the reasons for this gap are manifold. They include institutional path dependencies, institutional inertia, and bureaucratic processes but all too often also risk aversion in R&D funding by state agencies (Kelly 1982; Ugur and Trushin 2022, 1210).

3 HISTORICAL EXAMPLES OF FAILED SCIENCE AND TECHNOLOGY COLLABORATIONS

Underperforming S&T collaborations are not a new phenomenon, of course. The history of science and technology provides many examples of S&T collaborations that were seen by contemporaries as failures. Indeed, the history of international research collaborations provides a rich well of experience to learn from, and the historical record is often quite eloquent and explicit. From a German perspective, two historical examples for underperforming science diplomacy projects stand out—or, more concretely, large-scale state-led S&T initiatives that tried and failed to incorporate international private research power. Both were defined by elements of competition and cooperation with the United States.

The Restructuring of European Science Organizations in the 1970s

By the 1970s, the practice of European Community S&T had fragmented European research efforts into distinct, but sometimes overlapping and competing, functionally specialized (and very expensive) multilateral science organizations, such as CERN for particle physics, ESO for astronomy, ESRO for space research, or ELDO for space launcher technology. This was seen in the early 1970s by the West German government under Chancellor Brandt as being historically understandable, but ultimately not very efficient and very “unstrategic project-driven integration” (Rieck 2024, 209). The government argued that S&T should not be seen as an end in itself but as being in the service of European integration to protect European technological autonomy from the United States, i.e., should serve more politically defined goals. This disenchantment of big science led Bonn to drive an institutional update of European big science organizations, such as the creation of a unified European Space Agency as a successor to both ELDO and ESRO to position Europe as the third space power.

America’s Strategic Defense Initiative in the 1980s

When the Reagan Administration launched SDI in 1983, there was hope in the German government under Chancellor Kohl that German industry would be able to attract significant American R&D funding. West Germany had been a trusted S&T partner, but soon—similar to what happened more recently with the CHIPS and Science Act—protectionist impulses prevailed, cutting out almost all international actors, both public and private. This was a missed science diplomacy opportunity, which ultimately led to a deepening of European science integration. The frustration in the incoming Kohl government that was very pro-American was palpable, with the Chancellor calling it behind closed doors “a big disappointment” (Rieck 2024, 368–369). Still, the Kohl government continued to integrate deeply with the United States, especially in space

exploration—with strong contributions to NASA’s Space Shuttle missions, especially a series of ESA-Spacelab missions (D1 in 1985, D2 in 1993) funded by Bonn that demonstrated a German autonomous mission control capability for space exploration.

The first case illustrates the limits of government-induced innovation if organized in large bureaucratic science organizations with overlapping mandates and no political definition of overarching goals. The second case, by contrast, shows that including technological contributions from powerful S&T partners could have been politically and technologically useful. Finally, both cases do not (yet) ascribe an important role to private S&T actors.

4 DIFFERENT MODELS OF COLLABORATION IN SCIENCE AND TECHNOLOGY

Today, a change can be observed in international R&D cooperation managed by ministries of science and technology, away from input orientation (funding, regulation) toward output orientation (solving predetermined concrete problems) in S&T. This has become possible due to the emergence of financially potent private research actors in fields such as artificial intelligence or space exploration. *So, how can private actor know-how, research cultures, and funding be put to work for the greater good, i.e., to achieve politically defined goals?* Given these new framework conditions, a spectrum of possible collaborative structures in S&T emerges, with different roles for and functions of the participating actors (Fig. 12.1).

On one side of the spectrum lies the *bureaucratic model of collaboration*, i.e., international science organizations. In super expensive research areas such as nuclear fusion (ITER), the state provides all the funding and through specialized agencies also the “direction” of research—and, thus, all the financial risk associated with this research. Multilateral settings tend to make these decision processes cumbersome and bureaucratic. This model can produce frontier research; however, it also leads to the early adoption of technologies that become entrenched (path dependency) but might not be the most suited to the problem. These expensive path-dependencies—e.g., a certain reactor

	international science organizations	innovation ecosystems	private actor-led research fields
State influence:	very high	very low	medium
Private actor influence:	very low	very high	high
Competition:	very low	very high	high
Cooperation:	very high	low	high

Fig. 12.1 Spectrum of possible collaborative structures in S&T. Source: Authors’ own compilation

technology or a particular kind of particle accelerator or telescope—make it extremely difficult to change the technological infrastructure later on. The prohibitive cost keeps out private S&T actors.

On the opposite side of the spectrum lies the competition-based *avantgarde model of collaboration* in which private actor-led research fields outpace state regulation. Here, different technologies are tried out, and the competitive mindset of private industry competing for the best technological solutions leads to a high degree of “technology openness” with almost no state interference. However, as private actors foot the bill of risky R&D, the incentives to collaborate are higher the more expensive the research becomes, but the incentives to share the fruits of such endeavors broadly (technology diffusion) are extremely low. A good example for this kind of collaboration is artificial intelligence.

In the middle of the spectrum lie *innovation ecosystems* that try to prevent some of the problems and combine a lot of the potential benefits mentioned above: The primacy of private R&D with strong elements of competition as well as less bureaucratic decision-making is conducive to technology openness. State funding after achieving predetermined milestones and long-term state contracts in the future reduce the financial risk of private actors and serve as incentives for public and private actors to come together in these collaborative ventures. State steering remains possible, through funding and regulation that guarantees that R&D serves defined (public) goals and prevents, say, unethical R&D. Regulation can also help diffuse research findings and technologies widely. The most prominent example here is space exploration that is quickly becoming a commercial enterprise (Boeing, Blue Origin, SpaceX), but private actors are now also being mobilized in other areas, even in nuclear fusion (Department of Energy 2025).

5 CONCLUSION

The starting point of this exploration was the limits of government steering mechanisms in S&T. Dissatisfaction with big science in the 1970s led to a reorganization of these organizations in West Germany and Europe around grand, deep problems. In the 1980s, Washington’s SDI dashed hopes for more transatlantic S&T cooperation in West Germany and beyond. By contrast, today, ministries of science and technology increasingly try to make use of the specific capabilities of private S&T actors—sometimes from around the world—to drive technological innovation, complement big science efforts, and boost S&T at home. Since 2006, a striking example in this context has been NASA’s Commercial Orbital Transportation Services (Hackler 2014) program as well as the agency’s Centennial Challenges to incentivize private actors to develop everything from lunar landers and rovers to lunar habitats and waste management (NASA 2025). These open calls are helping create NewSpace innovation ecosystems that include a wide array of commercial actors, apart from research institutes, big science organizations, and government agencies. The German

Federal Ministry of the Economy (that funds the German space program) is similarly trying to mobilize the creativity of large private enterprises and start-ups (often spun out from universities or publicly funded research institutes) to solve specific technological problems such as the microlauncher competition to develop “a commercial and cost-effective access to space” (BMWK 2023, 23). In early 2025, it has also created a Space Innovation Hub at the German Aerospace Center DLR “to connect providers and users of space technologies” with “the goal of speeding up the putting into practice of ideas” (DLR 2025; BMWK 2023, 23). Neither NASA’s nor DLR’s competitions include a science diplomacy element yet.

Looking at historical and present-day examples of large-scale disruptive science and technology (S&T) projects, it becomes clear that both sets of actors have a role to play. This development has ramifications for science diplomacy too. It represents an important paradigm shift in modern S&T policies that is changing the way privately and government-funded research interacts, leading to a new quality of collaboration in international and transnational science.

How can this be achieved without national S&T protectionism and instead reinforce important science diplomacy principles such as openness and integration? Innovation ecosystems need to be designed to be as open, inclusive, and international as possible, so as to prevent S&T protectionism and improve the international and transnational S&T integration that is the backbone of science diplomacy. Open S&T ecosystems seem to be the most promising avenue to generate disruption and spread the benefits of innovation widely (Bacon et al. 2019). They could also be a useful way to help inform S&T policies, thus making the policy-making process more technocratic and more immune from purely political considerations. They might also help narrow the creation-translation-implementation gap by allowing a wider variety of R&D actors to participate in innovation making (input side) and by improving the production of disruptive innovation and global public goods (output side). As the great power competition continues to heat up, such (geo)political considerations will only weigh more on science diplomacy.

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Empowering Women in STEM in Emerging Economies Through a Science Diplomacy Approach

S. Ayse Kadayifci-Orellana and Derya Buyuktanir Karacan 

ABBREVIATIONS

AAAS	American Association for the Advancement of Science
AI	Artificial Intelligence
COMNAP	Council of Managers of National Antarctic Programs
EIGE	European Institute for Gender Equality
ESA	European Space Agency
EU	European Union
IASC	International Arctic Science Committee
ICT	Information and Communication Technologies
ITU	International Telecommunication Union
IWPR	Institute for Women's Policy Research
MBRSC	Mohammed bin Rashid Space Centre
MENA	Middle East and North Africa
MWM	Million Women Mentors
NASA	National Aeronautics and Space Administration
OECD	Organisation for Economic Co-operation and Development

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J. Lüder, M. Wählich (eds.), *The Palgrave Handbook of Science Diplomacy*,
https://doi.org/10.1007/978-3-032-29473-9_13

PRI	Polar Research Institute (Türkiye)
R&D	Research and Development
SCAR	Scientific Committee on Antarctic Research
SDCfA	Science Diplomacy Center for Africa
SDGs	Sustainable Development Goals
SESAME	Synchrotron-light for Experimental Science and Applications in the Middle East
STEM	Science, Technology, Engineering, and Mathematics
T3	Turkish Technology Team Foundation
TUA	Turkish Space Agency
TÜBİTAK	The Scientific and Technological Research Council of Türkiye
TÜSEB	Health Institutes of Türkiye
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WEF	World Economic Forum
YTB	Presidency for Turks Abroad and Related Communities
YÖK	Council of Higher Education (Türkiye)

1 INTRODUCTION

The world is undergoing a fundamental transformation driven by rapid technological advancements, fundamentally altering how we live, work, and think. This transformation has significant implications for the role of women in society, particularly in the fields of science, technology, engineering, and mathematics (STEM). With the advent of automation and the Fourth Industrial Revolution, low-skilled jobs, many traditionally held by women, are at high risk of being displaced (Huyer 2015; Bello et al. 2021). According to studies, sectors relying on highly skilled occupations are less likely to be automated. Yet, women make up a disproportionate percentage of employees in jobs with a high risk of automation. For instance, a report by the Institute for Women's Policy Research (IWPR) found that jobs predominantly held by women—such as cashiers, secretaries, and bookkeeping clerks—are among those most susceptible to automation in the future. The IWPR's report, “Women, Automation, and the Future of Work,” highlights that women constitute 58% of workers in occupations with a high risk of automation, despite representing only 47% of the overall workforce (Institute for Women's Policy Research 2019, 13). Recent analyses also show that women globally are disproportionately exposed to the risks of automation and generative AI, with research finding that women are nearly twice as likely as men to hold jobs at high risk of automation and that occupations traditionally held by women are more likely to be transformed by AI technologies (Credera 2025). Therefore, as we enter the digital age, the demand for higher-level education and advanced STEM skills will surge, but

women risk being left behind without deliberate interventions. Also, in developing nations, women are less likely to have access to the internet and mobile technologies compared to men, further widening the gender gap in digital literacy.

Therefore, institutional policies must ensure equitable access to education, technology, and skill development to bridge this emerging gap. A critical factor in preparing today's youth, especially young women, for future careers lies in addressing the disparity in access to digital tools and education. For women to take advantage of the opportunities presented by technological developments, they must be granted equal access to the technological enablers of the future.

Here is where science diplomacy can become a tool for change. Through international cooperation, countries can share best practices, establish gender-sensitive educational reforms, and create opportunities for women in STEM. By engaging in international scientific dialogue, nations can push for global standards that advocate equal access to education and technology, positioning women to succeed in an increasingly digitized workforce. As nations also collaborate across borders to address global challenges, science diplomacy can serve as a platform to advance both scientific innovation and gender equality.

This chapter emphasizes the prominence of addressing gender disparities, promoting equality, and elevating women's leadership in science, technology, and diplomacy through a science diplomacy perspective. By dismantling traditional barriers and cultivating a globally inclusive scientific community, increasing women's participation in STEM not only advances gender equality but also contributes to sustainable development by integrating diverse perspectives and expertise into global scientific and diplomatic efforts. Toward that end, it examines the pivotal role of science diplomacy in empowering women in Türkiye and the United Arab Emirates (UAE), focusing on policies and programs to boost female participation in science and research. The cases of Türkiye and the UAE are highlighted due to their unique similarities and differences, offering valuable insights into the role of gender empowerment through their national programs and international collaborations. As emerging economies, both countries have developed their science and technology sectors as a national priority. Türkiye, a nation bridging Eastern and Western cultures, and the UAE, a high-income developing market economy and conservative Muslim country, present contrasting yet complementary contexts for this analysis.

Despite their cultural and geopolitical differences, Türkiye and the UAE recognize the importance of promoting gender equality in STEM to drive innovation, strengthen social and economic development, and enhance their global influence and soft power. By examining the tailored initiatives of these two nations and their international efforts in science collaboration, this chapter illustrates how addressing gender disparities within diverse regional and cultural contexts supports national, international, and global objectives.

2 RETHINKING SCIENCE DIPLOMACY: POWER, EQUITY, AND THE ROLE OF GENDER

While rooted in historical interactions between science and diplomacy, science diplomacy has only recently been formalized as a field of study and practice. The early twenty-first century marked a pivotal shift, with science diplomacy emerging as a tool to leverage science and technology in international relations and foreign policy. This approach is widely acknowledged for its potential to address global challenges, promote development, and foster collaborative solutions to shared problems, especially in the context of international cooperation (Ruffini 2017; Trobbiani and Hatzenboer 2018; The Royal Society and AAAS 2010; Van Langenhove 2017; Turekian 2018; Ruffini 2020a; Turekian and Kishi 2017). The historical milestones, such as the establishment of the AAAS Center for Science Diplomacy in 2008, the 50th anniversary of the Antarctic Treaty in 2009, and the 2009 United Kingdom meeting at Wilton Park on the “New Frontiers in Science Diplomacy,” were critical in shaping this evolving field (Buyuktanir Karacan et al. 2024). Initially adopted by countries with robust research infrastructures, science diplomacy has gained traction in emerging economies and the developing world, becoming a recognized tool for fostering trust and cooperation through shared scientific efforts.

Despite its successes, science diplomacy has faced criticism for occasionally reinforcing power imbalances between nations and not being inclusive. Some scholars also argue that it can be overly idealistic, masking competition where science and technology are wielded for dominance rather than cooperation (Flink 2020; Ruffini 2020b; Davis and Patman 2015a, b). This critique underscores the need for science diplomacy to be adapted to the needs of developing countries, where resource and power asymmetries can exacerbate existing inequalities. Discussions around the practice of science diplomacy in the Global South highlight the need for more inclusive approaches, ensuring that underdeveloped countries benefit equitably from global scientific collaboration (Büyüktanır Karacan and Ruffini 2023).

Further advancing the conceptual debate, recent high-level policy reports signal a decisive shift in how science diplomacy is understood and practiced. The AAAS–Royal Society report *Science Diplomacy in an Era of Disruption* revisits the influential 2010 framework of *Science in Diplomacy, Diplomacy for Science, and Science for Diplomacy*, arguing that it reflects a first-generation, relatively optimistic understanding that no longer captures the complexity of contemporary science–policy interactions (AAAS and The Royal Society 2025). Drawing on contributions from experts across diplomacy, science, the private sector, and civil society worldwide, the report situates science diplomacy within a far more contested landscape shaped by rapid technological change, shifting geopolitical power balances, and heightened strategic competition in science, technology, and innovation. In parallel, the European Commission’s *A European Framework for Science Diplomacy*, developed through the collective input of 130 experts in the EU Science Diplomacy Working Groups, proposes

a renewed and more policy-oriented approach that explicitly incorporates an emerging fourth dimension of science diplomacy: Diplomacy in Science (European Commission 2025a, b). Together, these reports expand the conceptual landscape of science diplomacy beyond earlier taxonomies, underscoring its evolution into a multidimensional, politically embedded, and increasingly strategic instrument in an interconnected and multipolar world.

A notable divergence between the two 2025 flagship reports lies in their treatment of gender within science diplomacy. While the *AAAS–Royal Society* report acknowledges broader issues of inclusion and diversity, it does not explicitly integrate gender as a structured analytical or policy dimension of science diplomacy, nor does it address gendered career pathways within the field. By contrast, the *European Commission’s A European Framework for Science Diplomacy* places gender considerations more clearly within its forward-looking policy agenda. The report explicitly recommends developing academic potential and sustainable career paths in science diplomacy while taking gender into account, positioning this as a prerequisite for retaining Europe as a global hub for excellence in science diplomacy research (European Commission 2025a, b, 68). Gender is also identified as a key component of future science diplomacy training programs (p. 70), and the report highlights the structural fragility of science diplomacy careers, noting that without institutional backing and career incentives that account for gender-specific challenges, sustained engagement by scientists, particularly early-career researchers, is unlikely (p. 71). In this respect, the EU framework moves beyond conceptual renewal to embed gender as a practical and strategic consideration in the professionalization and long-term sustainability of science diplomacy.

Despite its origins in developed countries such as the United States, Germany, Japan, Switzerland, the United Kingdom, and France, science diplomacy is increasingly gaining traction in developing nations (King et al. 2021; Gluckman et al. 2017; Buyuktanir Karacan and Baran 2023). However, beyond discussions about its role in foreign policy and international collaboration, there remains an urgent need to address gender dimensions within the framework of science diplomacy. Integrating gender considerations is essential for ensuring that science diplomacy efforts are inclusive and equitable, promoting the contributions of women in science and technology, and addressing the unique challenges they face. Integrating gender perspectives into science diplomacy enhances its effectiveness and aligns it with global initiatives to achieve gender equality across all sectors. This approach acknowledges the critical role of women in scientific and diplomatic arenas, promoting inclusive policies and practices. For instance, the Science Diplomacy Center for Africa (SDCfA) hosted a webinar titled “Empowering Women in Science Diplomacy,” which provided a platform for dialogue and the exchange of ideas on advancing gender equality in science diplomacy (Science Diplomacy Center for Africa 2024).

Most countries engaged in science diplomacy tend to focus on one or, at times, several of the core dimensions of access, attraction, cooperation, and influence. In the context of this analysis, however, particular attention is given

to influence, as for the two case countries examined here, this dimension plays a comparatively more significant role than the others. Influence refers to “the capacity of a country to shape decisions and events” and extends beyond traditional power structures. It encompasses recognition by scientific communities, active participation in international organizations through scientific and technical expertise, strong representation in decision-making roles (including access to executive positions), and hosting significant research organizations or infrastructures (Ruffini 2017). This enables a country to shape public opinion, influence decision-makers, and impact political or economic leaders globally, contributing to what is often referred to as “soft power” (Flink and Schreiterer 2010).

As mentioned, by ensuring that women’s voices and contributions are recognized and valued, science diplomacy can become a more effective and equitable tool in addressing global challenges. Addressing the gender gap within this context will ultimately contribute to more just and inclusive international relations and sustainable development by integrating diverse perspectives and expertise, fostering a science diplomacy that genuinely reflects the diversity of all who participate. Women bring different perspectives and inclusive leadership styles, which can enhance collaboration, innovation, and trust in international spaces. Increased representation of women in decision-making and scientific leadership positions could amplify a country’s influence in global discourse, fostering a more balanced and equitable approach to addressing international challenges.

Gender and Science Diplomacy: Dual Forces for Progress

Globally, women are significantly underrepresented in STEM fields, and this disparity threatens to widen as the world shifts toward a more technology-driven economy. “Despite some progress in recent decades, with varying success depending on disciplines and countries, gender equality in science remains elusive.” (UNESCO 2024). According to the UN Report, despite some progress, only 28% of all engineering graduates and 22% of artificial intelligence professionals are women, reflecting the persistent gender gap in critical sectors of the future workforce.

However, these figures mask wide variation at both national and international levels, and some of the high-income countries and regions have a surprisingly low proportion of women in STEM fields. For instance, in Western OECD countries (e.g. the USA, Europe), women comprise less than 40% of ICT occupations, and only 27% of engineers are women in the USA and Europe (Cheryan et al. 2024). According to the EU’s *She Figures* (2021) report, in 2018, women remained underrepresented across STEM fields, R&D, and entrepreneurship, facing systemic barriers that limit their contributions and opportunities. According to the most recent *She Figures* report, despite near gender parity in overall EU employment, women remain significantly underrepresented in STEM professions, particularly as scientists, engineers, and researchers, and are more concentrated in technical and support

roles rather than research positions. Persistent gender gaps are especially evident in the business and ICT sectors and among self-employed professionals, reflecting enduring structural barriers to women's full participation and advancement in science and technology (European Commission 2025a, b, 77).

In STEM, women account for only 20.8% of doctoral graduates in Information Communication Technologies and 27% in engineering, reflecting persistent horizontal segregation that steers women toward fields like education and health sciences (EU 2021, 42). In R&D, women make up just 32.8% of researchers (EU 2021, 94), with significant underrepresentation in leadership roles and outputs, such as patent applications, where women hold just over 1.2 in 10 inventorships (EU 2021, 245). Funding disparities further hinder their ability to lead projects and advance research. In entrepreneurship, women constitute less than 25% of self-employed professionals in science and technology, often encountering challenges in accessing resources and networks (EU 2021, 60). Targeted policies like the EU's Gender Equality Strategy and Horizon Europe aim to address these gaps by promoting inclusive ecosystems, supporting women-led initiatives, and fostering mentorship and funding opportunities. Bridging these disparities is crucial for leveraging women's potential to drive innovation and growth in these critical sectors.

This underrepresentation in STEM education translates directly into fewer employment opportunities in high-tech industries, where automation is likely to displace low-skilled jobs, many traditionally held by women. A UNESCO study found that women make up 70% of employees at high risk of automation, compared to just 43% in jobs requiring advanced technical skills (Bello et al. 2021, 130). With the rise of automation and artificial intelligence, sectors that depend on highly skilled workers, such as technology and engineering, are expected to be more resilient. However, without deliberate interventions to increase women's access to STEM education and technology, women risk being disproportionately affected by job losses in the new economy model. In developing countries, the digital gender gap is even more pronounced, with fewer women than men accessing the internet and digital technologies, critical STEM education, and career enablers.

These statistics highlight the urgency of implementing institutional policies and international collaborations—such as through science diplomacy—to ensure that women are not left behind in the technological transformation of the global economy. Targeted policies to improve women's participation in STEM could help bridge this gap and ensure a more inclusive workforce for the future. Dismantling gender stereotypes and biases in science by enhancing the visibility of female role models through efforts including highlighting discoveries and stories from female scientists, increasing the presence of female scientists in media, ensuring equitable representation of women and men on science boards, committees, and panels and growing opportunities for women scientists to access grants are other ways in which this gap can be closed.

In recent years, there has been a growing recognition of the importance of increasing the participation of women in diplomacy, particularly through roles

as science diplomats (Ruffini 2022; Smith and Kozielska 2024; WISDA 2024). However, women continue to be underrepresented in the field of diplomacy as well, with only 20.54% of ambassadorships held by women as of 2023, marking a mere 5% increase over the past decade (Smith and Kozielska 2024, 5). This emerging field offers women unique opportunities to represent their countries in global forums on scientific innovation and policymaking. It ensures women scientists have access to international research networks, educational resources, and leadership opportunities. This inclusion is vital for addressing the gender gap in STEM, as it enables women to lead significant scientific initiatives, which can be transformative for individuals and the societies they represent. As more nations integrate science diplomacy into their agendas, the recognition of the need to prioritize gender equality within these efforts continues to grow. As more women take on these roles, they help shape global scientific agendas and become role models for future generations, inspiring young women to pursue careers in science, technology, and international relations.

One of the fundamental mechanisms to advance gender equality is developing gender-inclusive policies. Through collaborative frameworks, countries can establish policies that increase the participation of women in STEM education and research, provide mentorship programs, and support career advancement for women scientists. Such international agreements and efforts underscore gender equality as a global priority (UN Concept Note 2020; UNESCO 2017), particularly in emerging economies where gender disparities in education and employment opportunities hinder regional development. Promoting such inclusive policies allows nations to advance their development goals while contributing to global progress in science and technology.

This dual focus on *science and gender equality* reflects the growing understanding that empowering women in STEM is not only a matter of equity but also essential for advancing scientific progress and global competitiveness. Recognizing the achievements of women scientists through awards, international conferences, and collaborative projects enhances their visibility, which is essential for inspiring future generations. This recognition not only encourages more women to pursue careers in STEM, especially in regions where societal barriers may limit their participation (Nielsen et al. 2017) but also strengthens the scientific ecosystem by bringing diverse perspectives to research and innovation. As nations seek to address global challenges like climate change and public health, recognizing and including women in science and science diplomacy is crucial for leveraging diverse perspectives and expertise to create innovative solutions.

Women in developing and emerging economies encounter significant obstacles, including unequal access to resources, discrimination, and underrepresentation in decision-making roles. International collaborations and national policies facilitate the sharing of best practices and successful strategies to overcome these challenges, enabling countries to implement practical solutions and reduce barriers for women scientists. This *exchange of knowledge and experience* is particularly beneficial for countries with limited resources, as it enables them

to adopt proven strategies without having to navigate these challenges in isolation. In countries like the UAE and Türkiye, specific initiatives exemplify the tangible impact of various initiatives and support by governments on women's empowerment in STEM, which serve as a force for progress, advancing scientific innovation and promoting women's rights simultaneously.

3 EVOLVING POLICIES FOR WOMEN IN SCIENCE: THE CASES OF TÜRKİYE AND THE UNITED ARAB EMIRATES

There is a common misperception that women in the Middle East and North Africa (MENA) regions are excluded from participation in scientific and diplomatic endeavors due to cultural and societal barriers. While it is true that women in the region, like their counterparts worldwide, face significant challenges regarding gender equality and access to opportunities, it is essential to recognize the increasing number of women participating in STEM fields across the region. In fact, despite the global underrepresentation of women in STEM, some MENA countries show significantly higher percentages, with women comprising nearly 50% of the STEM students in certain areas (Margit 2021). For instance, according to a UNESCO report (2017), women in the MENA region have made substantial strides in higher education and STEM-related fields. In several countries, the percentage of female graduates in STEM surpasses that of male graduates. According to UNESCO (2017), up to 57% of all STEM graduates in Arab countries are women. "With an average population-weighted score of 63.4%, Middle East and North Africa has the second largest gender gap to close, after South Asia." (World Economic Forum 2022). While these numbers are promising, much work remains to be done. Despite these advances in education, there remains a significant gap in gender representation within the workforce (World Economic Forum 2022, 304–305), especially in senior leadership positions.

Türkiye and the United Arab Emirates (UAE) provide compelling examples of how emerging economies can foster women's participation and leadership in STEM fields. Türkiye, with its geographically strategic position bridging Europe, the Mediterranean, and the Middle East and its cultural ties to the broader Muslim world, serves as a unique connector between East and West. These two countries demonstrate their commitment to reducing gender gaps and advancing women's roles in science and technology through scholarships, research grants, and mentorship programs.

For instance, although Türkiye ranks low in the World Economic Forum's Gender Parity Index for its region, scoring 49.3 points, it boasts a comparatively high proportion of women in STEM, with 34.69% of STEM graduates being female (World Economic Forum 2022, 343; World Bank 2024). Furthermore, Türkiye has made notable progress toward gender parity in technical roles, showing a steady improvement of 12 points in recent years (World Economic Forum 2022, 19). On the other hand, the UAE stands out as a notable country in the region, with a strong representation of women in

science. UNESCO figures show up to 57% of Science, Technology, Engineering, and Mathematics graduates in Arab countries are women, while in the United Arab Emirates 61% of university STEM students are female (Euronews 2022).

The next section of this paper will examine Türkiye and the UAE in greater detail, highlighting the policies and strategies that have contributed to their progress in fostering gender parity in STEM fields.

Case Study: United Arab Emirates—A Space for Women in STEM

Nations increasingly utilize science diplomacy as a *soft power* tool to advance progressive gender policies while engaging in international scientific endeavors. By showcasing their commitment to gender equality in science, countries enhance their global reputation and attract partnerships that further their scientific and diplomatic objectives. The UAE's ambitious space program, led by a significant proportion of women scientists, is a prime example of this strategy (Al-Rostamani 2021). The Emirates Mars Mission positioned the UAE as a rising spacefaring nation. It highlighted its efforts to promote women's empowerment in STEM, strengthening its soft power by enhancing its global reputation on the global stage by showcasing its commitment to gender equality in science (UNSDG 2022). Moreover, ensuring more women have a seat at international scientific organizations and initiatives helps integrate their perspectives into shaping global scientific agendas and supports their soft power by presenting their contributions to more comprehensive and inclusive decision-making processes.

The United Arab Emirates (UAE) has positioned itself as a regional leader in promoting women's empowerment in STEM fields, mainly through its space program and leadership initiatives. The UAE has taken significant strides in incorporating women into its burgeoning space sector. The UAE Space Agency, under the leadership of Sarah Al Amiri, exemplifies the nation's commitment to integrating women into pivotal roles in space exploration. Al Amiri, the Minister of State for Advanced Technology and Chair of the UAE Space Agency, has become a key figure in gender empowerment (UNSDG 2022). Initiatives like Space Ed-Ventures, linked with the Arab Youth Venture Foundation, have provided Emirati high school students, including young women, opportunities to engage in aerospace engineering and youth space training programs at NASA's Johnson Space Center. These programs emphasize engineering-focused projects and hands-on activities to inspire students toward STEM careers.

The UAE's policies, such as The National Policy for Empowerment of Emirati Women 2023–2031, explicitly aim to facilitate equitable and comprehensive participation of women in all sectors, including education, emerging technologies, science, and the labor market (WAM 2023). Initiatives such as the UAE Gender Balance Council (2015) ensure women have equal opportunities in space science and technology, among others. Government-backed campaigns emphasize the importance of women's contributions to the nation's

technological and scientific achievements, spotlighting the role of women in space missions as national pride. The UAE has implemented various programs to encourage young women to explore careers in space sciences (UAE Space Agency [n.d.](#)). For instance, the National Space Program Scholarships aim to support Emirati students, particularly women, in pursuing education in aerospace engineering, astrophysics, and related fields. The UAE also offers Space Exploration Summer Camps that provide hands-on learning experiences for high school and university students, focusing on engaging young women in STEM. Also, the UAE Astronaut program aims to train Emirati astronauts, particularly women, for future missions (MBRSC [2017](#)).

UAE continues to prioritize policies that encourage women to pursue careers in space and technology, recognizing the strategic importance of these sectors for both scientific and diplomatic influence (ITU Hub [2021](#)). The Mohammed bin Rashid Space Centre has promoted women's participation in projects like the Emirates Mars Mission and the Rashid Rover (MBRSC [2017](#)). The UAE is planning a lunar rover mission, named Rashid Rover, which includes women scientists and engineers in its team (UAE Government Portal [2023](#)). Female scientists and engineers have been integral to the planning and execution of these missions, marking a progressive step toward gender inclusion in STEM within the UAE. Mars 2117 Strategy, an ambitious program to establish a human colony on Mars by 2117, aims to include gender-balanced teams, reflecting the UAE's commitment to equality in all facets of exploration. The Hope Mars Mission is one of the achievements, with a significant portion of the team comprising women. Women comprised 34% of the team working on the Emirates Mars Mission, with Nora Al Matrooshi joining the UAE space program as the Arab world's first woman astronaut (SatellitePro ME [2020](#); ITU Hub [2021](#)). Furthermore, the UAE collaborates with space agencies such as NASA and the European Space Agency (ESA), providing opportunities for Emirati women to engage in international space research and missions (AlMatrooshi [2019](#); NASA [2021](#); UAE Embassy [2019](#)).

These programs and efforts demonstrate the UAE's commitment to space exploration and its deliberate efforts to ensure gender inclusion at the highest levels of scientific endeavor. As Al Amiri herself has highlighted, the Hope Mars Mission is a "message to all Arab youth that if you put your mind to something, you can achieve it," illustrating the UAE's vision for empowering women through STEM (Bani-Issa et al. [2024](#)).

Another key initiative that showcases the UAE's commitment to supporting women scientists is the L'Oréal-UNESCO for Women in Science Awards (L'Oréal [2023](#)). This program recognizes and funds exceptional female scientists, both regionally and globally, further promoting the integration of women in scientific research. Through this program, the UAE's partnership with UNESCO highlights its focus on international scientific achievements, positioning the nation as a strong advocate for gender equality in STEM fields. The program encourages young women to pursue research by providing grants and

mentorship, empowering them to become leaders in traditionally male-dominated fields (L'Oréal 2024).

The Women in Research Initiative at the University of Sharjah also focuses on empowering women in scientific research (Bani-Issa et al. 2024, 5). The University of Sharjah actively empowers women in scientific research through initiatives like the Forum for Women in Research, known as “QUWA” (University of Sharjah 2024; Bani-Issa et al. 2024, 5). This annual forum, organized by the Office of the Vice Chancellor for Research and Graduate Studies in cooperation with the Research Outreach Department, aims to support women in research at local, regional, and international levels. It provides a platform for female researchers to present their work, engage in seminars and workshops, and access research funding opportunities. The forum fosters skills and capabilities necessary for women to excel in STEM careers, building a pipeline of women poised to make significant contributions to scientific discovery and global innovation. Supported by international partnerships, the initiative fosters the skills and capabilities necessary for women to excel in STEM careers. The program offers seminars, workshops, and research funding to female faculty, students, and researchers, building a pipeline of women poised to make significant contributions to scientific discovery and global innovation (University of Sharjah 2024; Bani-Issa et al. 2024, 5). These initiatives underscore the UAE's approach to creating an environment conducive for women in STEM to foster international collaboration and break down barriers to gender equality in scientific fields.

Case Study: Türkiye—Government Policies, International Engagements, and National Initiatives

Türkiye, the world's 17th largest economy according to 2023 (World Bank 2024), has adopted a multi-faceted approach to promoting women's participation in STEM through government policies and institutional support. It also strengthens its international collaborations that promote and support women researchers. These efforts have enhanced and encouraged more women to participate in research and innovation. However, its ratio of female to male engineers and scientists is outperforming the EU average, women remain underrepresented in STEM fields as well as in decision-making positions (UNDP 2024).

The key players in Türkiye's potential in science diplomacy include research infrastructures and universities, and funding institutions like TÜBİTAK (The Scientific and Technological Research Council of Türkiye), Turkey Health Institutes Presidency (TÜSEB), Presidency for Turks Abroad and Related Communities (YTB), and the National Agency (Büyüktanır Karacan 2021; Tufan 2024). Particularly, TÜBİTAK offers a range of programs to support women in science, including fellowships and research grants for women pursuing careers in STEM to empower them to bridge the gender gap in scientific fields. These programs align with Türkiye's objectives of increasing female

representation in academia and research, reinforcing the importance of gender-sensitive policy reforms in education and employment (TUBITAK 2024). For instance, the For Women In Science National Fellowship Program, with the collaboration of L'ORÉAL Türkiye and the Turkish National Commission for UNESCO, offers fellowships for Turkish women pursuing their research careers in Türkiye in the fields of life & environmental and physical sciences to promote, enhance, and encourage the contribution of women (TUBITAK 2023).

To promote women's participation in academic research, the Scientific and Technological Research Council of Turkey (TÜBİTAK) and the Council of Higher Education (YÖK) have supported various initiatives focused on women's empowerment. In 2015, YÖK established the *Women in Academia Studies Unit* (YÖK Akademide Kadın Çalışmaları Birimi) to advance gender equality in higher education. It has also played a role in collecting and sharing data on women in STEM, aiming to foster a more inclusive and equitable academic environment in Türkiye (YÖK 2021). Building on these efforts, TÜBİTAK established the *Women's Studies Commission* in 2019, a separate yet collaborative body that includes representatives from both TÜBİTAK and YÖK. This dual-initiative structure reflects a comprehensive approach to strengthening women's representation and contributions in academia through partnerships with international organizations, advocacy campaigns, and scholarship programs. Professor Zeliha Koçak Tufan, a leading figure in this initiative, has significantly contributed to advancing women's roles in academia and research. Between 2021 and 2024, she served as Türkiye's education attaché in the United States. During this tenure, she actively worked to build international connections for Turkish higher education institutions, especially in the absence of a dedicated science education attaché. Her efforts primarily focused on promoting the scientific diaspora of Türkiye, strengthening collaborations between Turkish and international institutions, and advocating for greater recognition of Turkish scholars in global academic networks. Another initiative to support women in STEM in Türkiye is the Million Women Mentors–Türkiye, also known locally as Milyon Kadına Mentor, initiative. This initiative is designed to create a robust network of mentoring programs that support female high school students, university students, and young professionals pursuing careers in STEM fields in Türkiye (Million Women Mentors 2024). The initiative aims to establish one million mentoring connections within ten years, welcoming male and female mentors to guide female mentees. By leveraging STEM connector's global expertise in supporting girls and women in STEM pathways and Turkish WIN's mentor-matching capabilities and expansive network of private sector STEM mentors, the program seeks to empower women in STEM careers and nurture a new generation of female leaders in Türkiye (Million Women Mentors 2024). Moreover, Türkiye's involvement in these international initiatives further supports the development of female STEM professionals through mentorship opportunities and international collaborations. These programs are designed to provide women with the tools

and guidance needed to excel in STEM careers, addressing the education-to-workforce pipeline and the leadership gap in scientific fields (Million Women Mentors Turkey 2024).

Facilitating international partnerships creates opportunities for diverse participation in scientific endeavors, enabling more women in STEM fields to engage with global research networks, access educational resources, and assume leadership roles. This collaborative approach not only promotes the exchange of best practices in gender equality but also supports the development of gender-sensitive policies and ensures the alignment of national strategies with international standards. This alignment demonstrates how international collaborations can catalyze policy changes at the national level, promoting a more inclusive scientific community. Türkiye has actively engaged in various international collaborations to advance these goals, three of which will be discussed below.

Turkey is a partner in the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), a flagship science diplomacy initiative fostering collaborative research in the Middle East and Mediterranean region (Rungius 2020). SESAME aims to bring world-class scientific research to the Middle East while promoting regional cooperation in science and technology (Smith 2012; Rungius et al. 2022). SESAME fosters an inclusive environment by providing training, networking opportunities, and access to cutting-edge facilities, enabling women scientists and researchers to advance their careers in STEM disciplines. Through collaborative research projects and capacity-building initiatives, SESAME helps bridge gender gaps, empowering women to contribute significantly to regional and global scientific progress. Through SESAME, Turkish women researchers gain access to high-impact research projects and training opportunities, contributing to scientific progress in an inclusive and collaborative environment. This initiative has enabled Turkish researchers, particularly women, to engage in regional collaborations and enhance their expertise. Turkish scientist Zehra Sayers played a pivotal role in SESAME as the co-chair of its scientific advisory committee. Her contributions were internationally recognized when she and four other scientists received the AAAS Award for Science Diplomacy in 2019. Her achievements highlight Turkey's growing impact on science diplomacy and its efforts to build regional and global scientific partnerships. This partnership highlights the increasing involvement of Turkish researchers in high-profile science diplomacy initiatives and underscores their ability to lead and contribute to international collaborations that advance science and technology. Their contributions inspire future generations, encouraging young researchers, especially women, to engage in science as a pathway to drive innovation, build international bridges, and address global challenges collaboratively.

Türkiye's participation in the EU's Framework Programs since 1984 underscores the EU's increasing emphasis on gender-inclusive policies as its policies and programs highlight the role of international collaboration in embedding gender equality into scientific research. For instance, the European Union's

Gender and Equality Strategy 2020–2025 and its gender focus in its policies (Genderaction 2020; European Commission 2024; EIGE 2024) highlight gender equality as a core priority for both EU research policy and external action. This priority is reflected and anchored in the EU's Action Plan on Gender Equality and Women's Empowerment in External Action 2021–2025, which aims for 85% of all new external relations actions to contribute to gender equality by 2025 (European Commission 2020). Science and Innovation Framework Programs like Horizon Europe, the European Union's key funding program for research and innovation, emphasize gender balance as a criterion for funding and participation. So, Türkiye's association with Horizon Europe allows it to align with these gender equality policies.

Türkiye has also actively engaged in scientific collaboration concerning Antarctica, establishing new institutions, implementing strategic policies, and signing the Antarctic Treaty to advance its presence and research in the region since 2015. Türkiye's Antarctic efforts aim to foster international scientific collaborations while strategically aligning its presence with broader foreign policy goals. Building on the foundational efforts of the Istanbul Technical University Polar Research Center (PolReC) in 2015, Türkiye conducted its first international polar expedition with 13 scientists collaborating with Ukraine's National Antarctic Science Center. The Polar Research Institute (PRI), established in 2019 under TÜBİTAK Marmara Research Center (MAM), has been instrumental in coordinating national Antarctic expeditions and research initiatives. One of the pioneering figures in Türkiye's Antarctic science diplomacy is Prof. Burcu Özsoy, a leading Turkish scientist and director of the PRI, who has played a critical role in shaping the nation's Polar policy from the very beginning (Caymaz et al. 2021; Arslan et al. 2024). Prof. Özsoy's leadership extends beyond scientific research; she has actively participated in international collaborations and represented Türkiye in key organizations, such as the International Arctic Science Committee (IASC), the Council of Managers of National Antarctic Programs (COMNAP), and the Scientific Committee on Antarctic Research (SCAR). Her contributions have been pivotal in aligning Türkiye's Antarctic strategies with global scientific and environmental objectives. Additionally, she serves as a role model for future generations of women and girls, inspiring them to pursue careers in STEM.

Türkiye is also actively promoting women's participation in space missions through initiatives led by the Turkish Space Agency (TUA) and affiliated organizations (Turkish Space Agency 2024). Elvan Kuzucu Hıdır, Chairperson of the Turkish Technology Team (T3) Foundation and a member of TUA's Board of Directors has expressed confidence that Turkish women will serve as astronauts in upcoming space missions (Daily Sabah News 2023). She highlighted the presence of female engineers in both public and private sectors of the space industry and encouraged women aspiring to work in space to maintain their motivation. Additionally, the T3 Foundation provides education to children under the "National Technology Initiative," with a significant proportion of girls participating, especially in Deneyap Technology

Workshops and TEKNOFEST competitions. This growing interest among female students in engineering faculties and space-related competitions indicates a positive trend toward increased female representation in Türkiye's space endeavors (Daily Sabah News 2023). These efforts reflect Türkiye's commitment to fostering gender diversity in its space programs, aiming to empower women to take on significant roles in the nation's space exploration activities.

As these initiatives show, Türkiye is actively fostering girls' participation in STEM, emerging technologies, and space exploration through various initiatives aimed at addressing gender gaps and building a diverse pipeline of talent. Programs like Engineer Girls of Türkiye provide scholarships, mentorship, and internships to female engineering students. At the same time TÜBİTAK offers grants and fellowships to empower women researchers and students in leadership roles within traditionally male-dominated fields. Initiatives like Million Women Mentors–Türkiye (Milyon Kadına Mentor) connect young women with STEM mentors. The Turkish Space Agency promotes inclusion by involving women scientists in satellite and lunar missions, supported by public-private partnerships and government-funded workshops focusing on artificial intelligence, robotics, and aerospace engineering. Through these efforts, Türkiye is creating pathways for women in STEM, addressing workforce needs in high-demand sectors, advancing gender equality, and strengthening its position in the global scientific community. Through international scientific collaborations, Türkiye has engaged in scientific communities, increased its scientific partnerships, and increased the participation of women scientists through these collaborative and interdisciplinary projects. These short and long-term science and innovation programs emphasize gender balance as a fundamental principle in research projects. Türkiye's alignment with these standards has been instrumental in shaping domestic policies that promote women's STEM participation and encourage more women to contribute to these fields.

Türkiye and the UAE exemplify how integrating women into STEM fields can be a cornerstone of science diplomacy, leveraging gender inclusion to foster international collaboration, advance national development goals, and enhance global standing in science and technology. In Türkiye, initiatives such as the Turkish Space Agency's programs, the Engineer Girls of Türkiye project, and TÜBİTAK's mentorship and research grants create pathways for women in STEM, addressing gender gaps and empowering future leaders in technology and space. Similarly, the UAE promotes women's leadership in STEM through policies such as the UAE Gender Balance Council, scholarships, and initiatives in its space sector, such as the Emirates Mars Mission and the Rashid Rover project, where women played key roles. These UAE and Türkiye case studies highlight the significance of engaging with international scientific communities and of empowering women and girls through diverse policies, tools, and role models. By aligning distinct strategies with their national development objectives, both countries build domestic

capacity, foster long-term career opportunities, and establish high-profile programs that enhance their global scientific image. These efforts not only contribute to scientific progress and gender equality but also provide powerful role models for other emerging economies, offering culturally relevant examples that resonate more strongly in similar contexts than those from developed nations.

4 CONCLUSION

This paper has explored the prominence of policies, programs, and tools that promote gender equality in STEM fields, particularly in emerging economies. Countries like the UAE and Türkiye, with their initiatives, could serve as regional role models by showing how inclusive policies and initiatives can effectively address gender disparities in STEM. By fostering international collaborations and creating gender-sensitive programs, these countries exemplify how targeted initiatives can help bridge gender gaps in science, technology, engineering, and mathematics.

However, across emerging economies, significant barriers such as cultural expectations, institutional limitations, and structural challenges restrict women's full participation and advancement in STEM careers. Despite high female STEM graduation rates, many women face obstacles such as inadequate support systems, limited access to leadership roles, and underrepresentation in research careers. The digital divide and economic constraints further complicate efforts in countries that lack the resources to implement robust, gender-sensitive STEM initiatives. Addressing these challenges requires a multi-layered approach, including policy reforms, institutional support, and societal shifts encouraging gender equity.

Emerging countries can collaborate internationally through science diplomacy to develop contextually appropriate and impactful strategies. Countries can enhance women's access to STEM education, professional development, and leadership opportunities by exchanging best practices, sharing resources, and fostering mentorship and role model networks. These collaborations not only support gender equality but also strengthen global scientific capacity, helping nations tackle pressing issues such as climate change, public health, and technological innovation.

For other emerging economies, these models offer culturally relevant frameworks that can be adapted to local contexts, avoiding the pitfalls of one-size-fits-all approaches. By building and investing in homegrown solutions, countries can challenge entrenched stereotypes, support economic and technological advancements, and contribute to the Sustainable Development Goals (SDGs). Empowering women as leaders in science and technology ensures diverse perspectives, drives innovation, and fosters inclusive growth. As countries face complex global challenges, including women in STEM will be critical to shaping a more resilient, equitable, and scientifically robust future.

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Women in Science Diplomacy Association

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1 RATIONALE

Science diplomacy plays a crucial role in navigating the complexities of today's challenges, including climate change, pandemics, and the implications of technological advancements, such as AI and large language models, quantum technologies, and biotech, all of which transcend national borders. The collaboration and involvement of scientists, policy makers, and diplomats are essential for overcoming these challenges. By leveraging scientific expertise, countries can

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address pressing issues more effectively, enhance public policy, and promote sustainable development (Science Diplomacy in an Era of, AAAS 2025; Aranda 2021).

However, the field of science and science diplomacy has long been male-dominated. Unbalanced representation leads to a science and policy landscape that ultimately lacks justification and acceptance. Additionally, this unbalanced representation limits diversity in perspectives and ideas, hindering innovation in finding solutions for complex global challenges. Moreover, the absence of women in these fields perpetuates stereotypes and systemic barriers, discouraging future generations of girls from pursuing careers in science and science diplomacy. These challenges apply to all underrepresented groups in these areas, including other gender minorities or representatives from the Global South.

The recently adopted Pact of the Future of the UN Summit of the Future underscores the necessity to close the divides in science, technology, and innovation—both between and within countries, particularly between developed and developing countries (United Nations n.d.). It also highlights the goal of advancing gender equality and the lives of all women and girls. This serves as the rationale for the creation of the Women in Science Diplomacy Association (WiSDA) to tackle exactly these issues and contribute to a more equitable and sustainable world.

2 WOMEN IN SCIENCE DIPLOMACY ASSOCIATION (WiSDA) MISSION AND VALUES

WiSDA is a pioneering initiative dedicated to promoting diversity and gender equality within the field of science diplomacy. Based in Washington, D.C., WiSDA is a globally focused organization fostering the representation of women in this crucial intersection of science and international relations. Established for educational purposes, the organization works to address gender imbalances in the field of science and science diplomacy, actively engaging its members in initiatives that promote gender equity in science, technology, and policymaking. Since its inception, WiSDA has grown to a robust community of over 100 women professionals working in science diplomacy in Washington, D.C., while its global reach is underscored by more than 600 members connected via its LinkedIn platform, generating significant engagement with over 2,000 post impressions each week (Women in Science Diplomacy Association n.d.).

WiSDA's mission is clear: to empower women in science diplomacy and create a platform where they can connect, mentor, support, and sponsor each other. The organization envisions a world where science diplomacy is inclusive and representative of all genders, recognizing the importance of diverse perspectives in shaping science and technology (S&T) policy at the global level. By addressing gender gaps and biases within S&T progress and decision-making, WiSDA is setting a precedent for a more equitable future in science diplomacy.

The organization's core values—Inclusiveness, Trust, Integrity, and Professional Excellence—guide its actions and initiatives, ensuring that all members are committed to these shared principles.

3 KEY ACTIVITIES AND INITIATIVES

WiSDA employs several strategies to achieve its mission. Through partnerships, the organization envisions a cohesive global growth strategy to support women science diplomats. By engaging partners from within its network, WiSDA builds a strong foundation for sustained progress. Additionally, WiSDA promotes volunteerism among its members, encouraging them to lead and participate in activities that align with the organization's goals. A key component of WiSDA's strategy is community-building, where mentorship plays a vital role. By cultivating one-to-one mentorship relationships, WiSDA maximizes its impact by delivering timely and sustainable policy recommendations.

WiSDA has a proactive approach to achieving its goals. One of its primary action items is to promote the representation of female and diverse researchers in global science and technology policy discussions, thereby influencing public perceptions and policy outcomes. Furthermore, WiSDA is focused on connecting diplomatic staff from embassies that do not have dedicated science officers to the Washington science and technology ecosystem. WiSDA will achieve this through active outreach, organizing orientation and networking events, facilitating introductions to policymakers, leading researchers, science organizations, and federal agencies as well as one-on-one mentorship. This is inclusive of inviting new non-traditional actors and their unique perspective into the multidisciplinary science diplomacy community supporting capacity building, knowledge sharing, and collaboration.

Additionally, WiSDA focuses on strengthening networks among women and diverse science diplomats, both within Washington, D.C. and globally, creating opportunities for collaboration and shared learning. WiSDA is represented in the EU Science Diplomacy Working Group and provides policy input to the development of the EU's Science Diplomacy strategy. It was also represented at the UN Summit of the Future in 2024.

Building a supportive global community is another key objective, as WiSDA aims to facilitate the exchange of best practices, resources, and knowledge among women science diplomats. This is especially imperative in countries with less representation and capacities in science diplomacy. Countries most affected by global challenges such as climate change, water scarcity, biodiversity loss, and least involved and with least access to future technological developments often lack the possibility to establish science diplomats in their governments and in international fora. Hence, WiSDA focuses on capacity building, offering teaching modules and online training to female diplomats.

The association is also committed to mentoring the next generation of women in science diplomacy, ensuring that the field continues to grow in diversity and expertise, e.g., by a partnership with the Science Diplomacy

Course of the Rockefeller University in New York to contribute to curricula development of the next generation of science diplomats.

One of WiSDA's flagship initiatives is the annual celebration of the International Day of Women and Girls in Science on February 11. During this event, WiSDA organizes a week-long series of activities to spotlight the achievements of women and girls in science, fostering greater awareness and support for gender equality in the field and focuses the week on emerging topics, such as artificial intelligence, quantum technologies, climate change, and arctic science, etc. Through such actions, WiSDA continues to inspire and empower women in science diplomacy around the world (Women in Science Diplomacy Association [2025](#)).

4 FUTURE FOCUS

The future of WiSDA is driven by an ambitious, forward-thinking vision aimed at amplifying the voices and contributions. WiSDA envisions a future where women play a leading role in addressing global challenges through science diplomacy in issues such as AI, quantum technologies, and biotech.

Expanding Membership and Global Representation

As WiSDA continues to grow, it aims to expand its membership by including women from underrepresented regions such as Africa, Latin America, Southeast Asia, and the Middle East. By fostering regional chapters and collaborating with international organizations like the United Nations and UNESCO, WiSDA hopes to increase opportunities for women in science diplomacy globally.

So far, WiSDA has opened a chapter in Canada, supported by the Italian Embassy in Canada. Moving forward, WiSDA aims to focus on opening chapters in the Global South, where countries like Zimbabwe and South Africa have already expressed interest.

Mentorship and Capacity Development

Recognizing that mentorship plays a critical role in empowering women to pursue and thrive in science diplomacy careers, WiSDA plans to enhance its mentorship programs. These programs will connect early-career scientists and diplomats with experienced leaders in the field, offering guidance, career advice, and networking opportunities.

WiSDA aims to establish a formal mentorship platform that enables mentees to connect with mentors based on their specific areas of interest. In addition to one-on-one mentorship, WiSDA will host leadership development workshops and training sessions to help women acquire the skills needed to navigate the complexities of science diplomacy.

Likewise, capacity building is crucial to WiSDA's mission. The association aims to expand its activities to regions with limited capacity for science diplomacy. To achieve this goal, WiSDA aims to partner with regional initiatives, build on existing diplomatic networks, and contribute to the local development of knowledge, experience, and capacity for science diplomacy with a global context.

Promoting Gender Equity in Science and Diplomacy

WiSDA advocates for greater female representation in scientific bodies, diplomatic missions, and policymaking positions by addressing the systemic barriers that prevent women from achieving leadership roles, such as unconscious bias, lack of access to funding, and work-life balance challenges. To achieve this goal, the association plans to collaborate with governmental and non-governmental organizations to create gender-sensitive policies and programs that facilitate women's participation in science diplomacy. WiSDA will also launch public awareness campaigns to highlight the contributions of women in science diplomacy, showcase success stories, and inspire the next generation of female leaders.

Fostering International Collaborations

The association plans to establish a platform for facilitating international partnerships among women in science and diplomacy. This platform will serve as a hub for connecting female scientists and diplomats from different countries, allowing them to collaborate on research projects, policy initiatives, and diplomatic negotiations. WiSDA will also host international conferences, workshops, and webinars that bring together women from diverse backgrounds to share knowledge, exchange ideas, and develop joint initiatives.

The association will prioritize partnerships that address pressing global issues, such as sustainable development, public health, environmental conservation, and technological innovations. By fostering these collaborations, WiSDA aims to ensure that women play a leading role in shaping the global scientific agenda and contributing to international peace and security through science diplomacy. A diverse and gender equitable science diplomacy community will be a key driver to face the challenges posed by disruptive new technologies such as AI and large language models, quantum technologies, and biotech.

5 RECOMMENDATIONS FOR POLICY MAKERS

To further these outlined objectives, governmental agencies and policymakers must take concrete steps to promote gender equality in science diplomacy, reflecting the growing number of women scientists and diplomats globally. This requires commitment to supporting and ensuring gender-balanced

recruitment processes for new science diplomats. By actively investing in outreach and integrating gender considerations into hiring and appointment procedures, governments and institutions can create a more diverse and representative workforce in science diplomacy. This not only promotes equity but also enhances decision-making by incorporating a broader range of perspectives and expertise ensuring that “Science is for all.”

Additionally, dedicated funding should be allocated to support global, gender-balanced networks of science diplomats to offset isolation and instead catalyze collaboration, knowledge sharing, and confirming best practices. These networks provide visibility and a crucial platform for leadership development, peer support, and mentorship, as well as orientation at new postings, enabling women and gender minorities to thrive in science diplomatic roles across the international ecosystem. Without long-term financial commitments and active outreach, many talented individuals—particularly those from under-represented regions without dedicated science diplomatic expertise—will struggle to access the necessary resources and opportunities to advance in their careers.

Furthermore, it is essential to create more pathways for women and gender minorities from developing countries to participate in science diplomacy. This can be achieved through structured training programs, professional development initiatives, and comprehensive onboarding measures when individuals take on new diplomatic postings. Many aspiring science diplomats face barriers such as limited access to education, institutional biases, and lack of peer support and mentorship. Addressing these challenges through targeted programs will help bridge the gap and foster a more inclusive international science diplomacy landscape.

Finally, raising awareness about science diplomacy as a viable and impactful career path across a range of academic disciplines in schools and universities is critical to developing a diverse future workforce. This effort should not be limited to scientists but should also include professionals in research administration and regulatory affairs supporting the global science ecosystem. Many students in science and technology, particularly young women and gender minorities, are unaware of the opportunities available in this field. By integrating science diplomacy topics into educational curricula, organizing career workshops, and promoting role models, institutions can inspire the next generation to pursue careers at the intersection of science and diplomacy. This early exposure is essential to cultivating a pipeline of talent that will contribute to global scientific cooperation and policymaking.

Acknowledgement WiSDA has received generous support from its members and partner organizations. WiSDA is supported in part by the Richard Lounsbery Foundation through its Officer Grant program.

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Science Diplomacy Hubs: The Johns Hopkins Science Diplomacy Hub

Ona Ambrozaite 

1 INTRODUCTION

International scientific cooperation has often been regarded as the crucial “glue” that helps to maintain and build bridges between nations, especially when political situations and international relations are fragile. National security, global health, sustainable development, and trade are some of the areas affected by science and technology advancements (Mauduit and Gual Soler 2020). Such a dynamic nexus has attracted interest from scholars at all career stages, whether in science or diplomacy sectors, to engage in cross-cutting issues in science diplomacy and provide their expertise to help establish and maintain bilateral and multilateral partnerships.

2 ROLE OF HIGHER EDUCATION INSTITUTIONS IN SCIENCE DIPLOMACY

The role of higher education institutions in facilitating such transnational science diplomacy partnership opportunities is of particular interest, where the institution’s strengths in research and academic expertise can be brought to global policy development conversations. Universities with science degree programs are particularly well-positioned to engage in science diplomacy knowing that scientists are natural diplomats, with strengths in collaboration and education that have great potential to be used in diplomatic arenas as well (Gast 2021). It has also been highlighted that university-based research institutes can have a prominent role in global governance, acting as conveners that bring together different groups that otherwise would not interact with one

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another (Weber and Duderstadt 2011). Research universities have the additional advantage of providing a neutral ground for diplomatic and policymaking conversations compared to those that could be carried out in conventional policymaking areas. By doing so, higher education institutions can foster the formation of new partnerships and networks while sustaining the already established ones.

Overall, it has been observed that national policies of higher education have increasingly shifted their focus to encourage international collaboration (Carraz et al. 2010). One of the countries that has extensively focused on the use of education, science, and technology as a diplomatic tool to overcome regional frictions since the 1930s is Brazil (Ferreira and de Oliveira 2020). The Brazilian education diplomacy strategy has been using both the so-called hard and soft powers of science since the beginning of the last century to establish dialogues with neighboring countries in Latin America. As has often been the case in multiple instances such as the U.S. relationship with the Soviet Union during the Cold War, Brazil has used the power of science diplomacy to establish scientific, cultural, and educational links to maintain relationships with countries when “political tensions did not allow traditional diplomacy to express itself fully” (Ferreira and de Oliveira 2020). Education and science diplomacy are complementary practices of Brazilian science diplomacy, concepts that are likewise applicable to the work of higher education institutions with feet in both of these worlds.

Therefore, to realize the full potential of science diplomacy, it is crucial for global higher education institutions such as the Johns Hopkins University to establish a science diplomacy hub that can be the hotspot where individuals working in relevant sectors come together to transition from dialogues to action. Such a science diplomacy hub can be the ideal entity to bring to light the scientific and technological issues relevant to international affairs.

3 JOHNS HOPKINS SCIENCE DIPLOMACY HUB

Recognizing the importance of bridging traditional silos between science and diplomacy and allowing scientists and diplomats to share knowledge and work together in a neutral setting, together with 2003 Nobel Laureate in Chemistry Prof. Peter Agre, we launched the Johns Hopkins Science Diplomacy Hub in 2023 in the heart of Washington, D.C., steps away from Capitol Hill, the White House, and other major federal institutions.

The Johns Hopkins Science Diplomacy Hub drew its inspiration from the university’s goals of bringing cutting-edge research and expertise to global policymaking at an ideal location in the nation’s capital. Such a unique hub based in a global higher education institution complements different initiatives in science diplomacy such as the Geneva Science and Diplomacy Anticipator (GESDA) based in Switzerland, an independent foundation founded by the Swiss Federal Council and the Canton and City of Geneva. The Johns Hopkins

Science Diplomacy Hub was created with the aim to bridge the educational and professional gaps between current and future professionals in the fields of science and diplomacy and contribute a contemporary perspective on science diplomacy.

With that in mind, the Johns Hopkins Science Diplomacy Hub has placed an important emphasis on international topics and connections of various delegations to bridge the often-siloed communities using the unique role of a higher education institution as a platform for science diplomacy with unique characteristics of neutral positioning, a plethora of expertise, and the ability to convene diverse stakeholders. To that end, the Johns Hopkins Science Diplomacy Hub has organized high-profile and high impact convenings where scientists, diplomats, policymakers, students, actors from the private sector, legal practice, and others could connect to learn about topics of Artificial Intelligence (AI), Quantum Information Science and Technology (QIST), climate change innovation, public health, data diplomacy, and more.

The Johns Hopkins Science Diplomacy Hub convenings created a fertile ground for scholars from science and diplomacy to examine alternative ways of thinking about various topics of relevance to science, technology, innovation, and policymaking on a global scale. Such science diplomacy convenings also offered unparalleled opportunities for university-based experts to practice translation of complex scientific topics using a language recognizable and usable by policymakers, leading to tangible impacts on technological regulations and new partnerships in relevant organizations.

4 JOHNS HOPKINS SCIENCE DIPLOMACY SUMMIT

One of the most prominent examples of the Science Diplomacy Hub activities has been the first of its kind Johns Hopkins Science Diplomacy Summit that has, since its launch in 2024, attracted more than 2000 attendees from 35+ countries who attended over two hundred of different high-level flash talks, panels, discussions, demos, and other sessions. The annual Science Diplomacy Summit focuses on scientific findings and their global impacts in AI, QIST, climate change innovation, public & personal health, space and ocean diplomacy, international partnerships, and other relevant topics. It has emerged as a key science diplomacy convening to facilitate exchange between experts working at the intersection of science and diplomacy and to connect stakeholders who otherwise don't have the opportunity to interact. The first Science Diplomacy Summit 2024 included sessions on topics such as "Science Advisors to the U.S. Secretary of State: Past, Present & Future," "Ambassadors & Science Diplomacy," "Diplomacy in Microgravity," and "How Does AI Change Art" that highlighted the multifaceted global nature of science, technology, and innovation fields such as Artificial Intelligence from a global policymaking viewpoint.

5 PIVOTAL ROLE OF YOUNG SCHOLARS

One of the central goals of the Johns Hopkins Science Diplomacy Hub has been to foster growth of a global science diplomacy network that can benefit from university research excellence. Aligning with one of the core goals of science diplomacy to provide evidence-based recommendations to policymakers, scientists at universities can engage in research that policymakers have an interest in, but often lack the time or resources to engage in on their own (Weber and Duderstadt 2011).

At the Johns Hopkins University, graduate students, whether in natural sciences, engineering, or international relations, were given the opportunity to engage in various science diplomacy writing collaborations with diplomats or graduate students in other countries to understand how science, technology, and innovation intersect with policy decision making around the world. The pivotal role of young scientific minds in forging international partnerships has been exemplified by highly successful long-term science diplomacy collaborations with diplomats and universities in their home countries such as Belgium, Japan, and Switzerland. Topics covered during such collaborative projects ranged from pesticide use reduction and healthcare management to key factors influencing science diplomacy expectations, work that has either been published or in preparation for publication (Ambrozaite et al. 2023, 2024; Sapin et al. 2025). By taking part in such unique science diplomacy collaborations, the early career scholars were able to directly influence the field of science diplomacy by providing concise evidence-based recommendations to the policymakers. Such tangible capacity building impacts have highlighted how direct involvement of early-career scientists can contribute to new forms of collaboration and tackling of global challenges through science diplomacy.

The abovementioned science diplomacy collaborations were initiated and cultivated by young scholars who believed in the power of scientists taking the initiative and developing independent efforts and international collaborations to solve the most pressing global problems we face today. While such unique science diplomacy efforts by doctoral degree candidates have been fostered in the United States, countries such as Japan, however, have seen an insufficient emphasis on the importance of doctoral degree holders in promoting an international atmosphere in Japan's scientific world (Carraz et al. 2010).

6 BUILDING NETWORKS ACROSS BORDERS

With the current volatile geopolitical landscape that is often intertwined with breakthroughs in technologies such as QIST, AI, synthetic biology, and space exploration, universities have the opportunity to become a key part of foreign policy development as evidenced by their ability to build networks, capacity, and reciprocity between nations. Building upon relationships and reducing silos to create strong collaborative networks are important challenges that the

power of science can help tackle by transcending geopolitical differences and sustaining engagement from policymakers.

Helping build bridges and establish multilateral structures that could act as launchpads for new science diplomacy connections was key. It allowed Prof. Peter Agre and I to create such a one-of-a-kind science diplomacy hotspot born at a major academic institution to equip the next generation of science diplomats to address complex geopolitical issues ranging from climate change innovation to competition and collaboration in the quantum technology space.

With the collection of some of the brightest minds in the world, higher education institutions such as the Johns Hopkins University can use their expertise in the multitude of fields to ensure that scientists are well positioned to be diplomats as well. Integrating science diplomacy into the overall university strategy, such as by establishing a science diplomacy hub, can help build the necessary bridges to increase understanding not only among fields of scientific research in different countries but on a higher level among nations, especially those with diplomatic tensions, as well. As one diplomat reflected, after speaking at our Science Diplomacy Summit, such a science diplomacy platform helps to not only realize what science diplomacy is overall but also that their role at the embassy is, in fact, that of a science diplomacy practitioner. The future is bright, and I hope that such a science diplomacy platform we pioneered at the Johns Hopkins University brings forth many more such moments of realization and acts as an inspiration for other institutions as well to become key players in global science diplomacy conversations.

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City Science Labs as Platforms for Science Diplomacy

Hilke Marit Berger  and *Gesa Ziemer*

1 BALANCING URBAN REALITIES: TWO CASE STUDIES AS AN INTRODUCTION

Hamburg 2023: the German government has passed a law to increase and accelerate the expansion of renewable energy (BMWSB 2022). Around 2241 hectares of land in Hamburg must be made available for wind energy by 2032. Germany aims to double its renewable energy production by then to reduce the impact of the climate crisis and end its dependence on fossil fuels, with wind power playing a key role in achieving this goal. The federal states are required to set aside 2% of their territory for the expansion of wind energy. The distribution of the areas to be made available takes into account the different conditions in the federal states. For Hamburg, this means that 100 new sites have to be made available in 2023 alone. As a densely populated city-state, the designation of so many sites represents an “enormous planning challenge” for the city (“Änderung des Flächennutzungsplans und des Landschaftsprogramms” 2024). A balance has to be struck between climate targets, affordable housing, and respect for people and the environment. Especially in Hamburg, the port and the airport, which is located in the city center are import stakeholders. This also involves big companies like Airbus and its approach routes. Authorities are struggling to come to terms with a lot of antagonistic needs, but they need to find a compromise quickly. But how?

The same city a few years earlier—a very different problem, but a similar challenge: In the cold winter of 2015–2016, more than 40,000 people (mainly from Syria, Afghanistan, and Iran) sought refuge in just 4 months. As the influx

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is so large in such a short period of time, people have to be accommodated in tents at times, despite considerable civil society engagement. This exacerbates an already politically charged situation, leading to populist tendencies and dramatic images of people camping on sidewalks and parks. The city has to provide temporary accommodation at very short notice. While fierce political and sometimes very emotional debates rage across Europe about the basic reception rules and fair distribution between countries, Hamburg, a rich German city of almost 2 million people, is faced with the concrete task of how to provide accommodation for so many people so quickly. There are hardly any vacant properties in the city, and buildings are already overcrowded in the very limited space available. Social and political tensions are rising. Right-wing populist forces are increasing. Citizens' initiatives are forming to hold a referendum to ensure that no more than 300 refugees are allowed to live in one accommodation, and that the places are at least one kilometer away from each other. Although this is an understandable demand, it would be impossible to implement in such a densely populated city (Weber and Ziemer 2022, 7–12). What to do?

2 DIGITAL SOLUTIONS FOR URBAN CRISES: HAMBURG'S CITY SCIENCE LAB AS A SCIENCE DIPLOMACY MODEL

While these are two local examples from Hamburg, managing urban spaces for renewable energy or accommodating large numbers of refugees are challenges faced by cities around the world. In Hamburg, these problems were the starting point for research projects carried out by the City Science Lab (CSL) of Hamburg's HafenCity University (a cooperation with the MIT Media Lab in Cambridge, USA) in close cooperation with the city administration itself. In the following, they serve as examples of how scientific institutions can take on a diplomatic mediation function between entrenched political fronts, in the sense of a communication platform, while at the same time developing very practical solutions to the problems at hand. The City Science Lab thus acts as a form of science diplomacy, mediating between different stakeholders—government, civil society, business, and academia. The CSL's approach to integrating local community insights and municipal expertise can be seen as a diplomatic effort to bridge the gap between top-down planning and bottom-up community input. The international exchange of knowledge facilitated by science diplomacy is thus of great benefit in addressing local challenges on a global scale.

In order to generate solution-orientated knowledge, the lab works in a transformative way, develops software in agile processes and conducts real-world labs or living labs. We work with an interdisciplinary team of researchers from the fields of software development, urban research, and social sciences on pioneering urban technologies such as digital urban twins, urban data platforms, software for scenario planning and location evaluation, digital citizen participation, co-creative applications in the fields of virtual and augmented reality (VR, AR) with a focus on geodata processing. The city of Hamburg

considers research to be an important aspect of its digital strategy, as it is a central player in the generation and realization of innovative projects and an integral part of a city-wide urban ecosystem (Hamburg Digital [n.d.](#)). And this with good reason: Cities today face an unprecedented convergence of crises, creating a complex polycrisis (Lawrence et al. [2024](#)) that challenges traditional urban planning and governance paradigms. As the global population increasingly concentrates in cities, these urban areas are rapidly evolving into intricate, multifaceted systems that generate unprecedented volumes of data. Cities have become epicenters of complexity, characterized by intricate networks of infrastructure, human activity, and information flows (Gallotti et al. [2021](#)). The digital era has ushered in new possibilities for understanding and managing such urban environments.

The wealth of information presents both challenges and opportunities for researchers, urban planners, and policymakers seeking to comprehend and optimize the functioning of modern cities and the quality of life. Accordingly, the impact of technology and how it is used for urban production has severely increased as is reflected in many political guidelines on the so-called “smart” or “digital city.” For example, in the UN Habitat international guidelines on people centered smart cities (UN-Habitat [n.d.](#)), as well as in academic reviews and handbooks (Reis et al. [2022](#)).

3 ENABLING INCLUSIVE URBAN TRANSFORMATION: DIGITAL TOOLS FOR MULTI-STAKEHOLDER COLLABORATION AND PARTICIPATION

Urban development processes require a high level of communication and cooperation between many different stakeholders. Thereby the quality of communication and cooperation is a central element of integrated and sustainable urban development and a prerequisite for cities to successfully deal with the current challenges. The framework for these communication processes changes with the digital possibilities at hand, for example, in regards of participatory democracy. These new digital planning tools impact rapidly the way in which urban governance or e-governance is facilitated (Silva [2022](#)). Technologies like machine learning can improve the effectiveness of citizen participation and open up new possibilities for engagements of multiple actors as well as for policy design and implementation (Arana-Catania et al. [2021](#); Thoneick [2024](#)). But such advantages, for example, improved decision-making, efficiency in planning, and various insights derived from data still come with significant challenges, including privacy concerns, data misuse, algorithmic bias, and the risk of overlooking essential qualitative aspects of life. These need to be addressed with improved education on digital literacy, better political guidelines, laws, and more transparency. Accordingly, finding out how to ensure that as many different voices as possible are included in urban decision-making processes, how to communicate the complexity of urban systems at a low threshold without negating the complexity or in a nutshell: developing such

technologies for the common good is a research task that cannot be left to private economic actors alone. The role of science here is to develop and mediate in equal measure. It's a scientific challenge to create spaces for the negotiation of emotionally and politically controversial issues, and thus to assume social responsibility especially in regards of power relations and hierarchies that are always part of participatory processes (Kühn and Berger 2026). The research of the CSL is dedicated to exactly this challenge: How can digital tools help to foster so called multi-stakeholder collaboration (from administration, politics, civil society, academia, and the private sector). How can people be enabled to improve the conditions for the needed transformational processes?

4 FROM CRISIS TO COLLABORATION: LEVERAGING DIGITAL TOOLS AND PUBLIC INPUT IN URBAN DECISION-MAKING

To practice new forms of digital collaboration, many cities are setting up City Labs as places where future scenarios for the city are developed together in an agile way, close to the needs of users, and often in real-life experiments (Ziemer 2021). The CSL was the first City Lab in Germany to focus on the digital city. It carries out applied and basic research projects with a multi-stakeholder approach in cooperation with politics and administration, civil society, business, and science. It was established 2015 with the project, *Finding Places* (City Science Lab Hamburg n.d.-a) in response to the challenge for the City of Hamburg to find temporary housing for thousands of refugees as described above. In partnership with the MIT Media Lab in Cambridge/USA, the CSL employed an innovative human-computer interaction tool, a so-called CityScope (MIT Media Lab n.d.) to facilitate a broad public participation process for urban decision-making. In more than 40 moderated workshops, more than 400 participants from the local neighborhoods proposed concrete areas and discussed the advantages and disadvantages in detail. One hundred and sixty-one commented proposals were sent to the city for consideration.

The project's primary objective was to facilitate a comprehensive citywide dialogue regarding the accommodation strategies and locations for the substantial influx of refugees in Hamburg. Concurrently, it aimed to elucidate the intricacies of the urban planning process to the participating citizens, fostering increased acceptance through enhanced understanding. This approach sought to synergistically integrate local knowledge from community participants with the expertise of municipal authorities and academic researchers. The discourse extended beyond the mere identification of individual sites, encompassing a broader debate that considered diverse interests (residential, commercial, and conservation) within the framework of legal planning requirements. This multifaceted approach enabled a more holistic examination of the urban fabric and its capacity to absorb and integrate refugee populations. By engaging citizens in this complex decision-making process, the project aimed to bridge the gap between top-down planning approaches and bottom-up community insights. This participatory model not only addressed the immediate need for refugee

accommodation but also contributed to a more inclusive and transparent urban governance paradigm. The project thus served as a case study in collaborative urban planning, demonstrating how cities can leverage diverse knowledge sources to address acute social challenges while simultaneously enhancing civic engagement and urban resilience.

5 FROM DATA TO DIPLOMACY: ENABLING PARTICIPATORY URBAN SOLUTIONS THROUGH TECHNOLOGY AND DIALOGUE

Today, the CSL serves as a place for dialogue between government, academia, civil society, and business on the basis of digitized data. We work on specific requests from the city administration, but also from business or civil society, and develop tools for collaboration, participation, and planning. In case of the opening challenge to find places for wind turbines, we conducted a series of workshops customized for the city administration, using our tool called COSI (Cockpit for Social Infrastructure) (City Science Lab Hamburg [n.d.-b](#)) to change the search framework from excluded to potential area and stimulate a discussion based on ongoing evaluation of the suggested spaces. Here, the lab functioned as a platform for the discussion between the expert groups, using the digital technology to deliver a neutral map-based perspective by modelling the impact and make room to discuss the consequences of potential decisions.

In the context of our research domain and ongoing projects, our primary focus is on developing and enhancing a city's digital infrastructure, with a particular emphasis on making it accessible and functional for all stakeholders. With the implementation of these technologies, citizens can comment on new residential areas; new mobility is implemented, modelled, and evaluated in pioneering projects; data platforms combine social and spatial data to develop a city's social infrastructure; and park areas can be designed with the neighborhood in virtual realities.

This is as close to citizens as possible and increasingly also in relation to urban AI applications. The topic of data storytelling is also becoming increasingly central, with artistic practices also being included. In this way, practice-oriented results such as software prototypes, digital platforms, and models, analyses or evaluations are produced, which actively support the digitalization of sustainable urban development in Hamburg.

With a view to international knowledge transfer, the CSL works together with the United Nations (UN Habitat/Nairobi and OICT/New York) in the UNITAC project (United Nations Innovation Technology Accelerator for Cities [n.d.](#)) and carries out digital projects in the field of regional and urban development globally with local partners. We work with local governments, universities, and stakeholders from civil society currently in Guatemala, El Salvador, Nicaragua, Costa Rica, Panama, Belize, Honduras, Hargeisa, Tanzania, Botswana, Ukraine, Namibia, South Africa, and Bangladesh. The question how to scale knowledge from a privileged industrialized context with political and social freedom and economic stability globally certainly comes

with a challenge because the local specifics are crucial to our work, and in many cities the situation is more challenging in terms of both the existing data situation and the availability of basic digital socio-technical facilities. There is simply less data, or there is data, but it is not made available on data platforms. There is also a lack of trained staff and resources, particularly in small towns or rural regions, to regularly update technologies and operate them sustainably. Especially in informal settlements where people have no legal status such as rent, ownership, or right to use the land they live on, in countries where basic infrastructure such as access to clean water, waste disposal, education, or health facilities are lacking, one thing above all becomes essential: simplicity is the key. However, this does not mean that the negotiation processes between different interest groups, the inclusion of marginalized groups, and the task of providing a platform for conflicting interest are less central. On the contrary, it is precisely here that the political dimension that research can take on becomes all the more visible and the diplomatic aspect of research-based action more central.

The research projects demonstrate the potential of digital collaboration as a key tool for addressing urban challenges and communicating complexity. The work illustrates how technology can be used to create more resilient, participatory, and adaptive cities when developed in a needs-driven way and in close collaboration with different stakeholders. In this way, City Science Labs become both a platform and a player in the search for solutions to complex problems and in informing new ways of making political decisions thus creating space for diplomacy: Combining the analysis, visualization, and simulation of urban data with collaborative processes with diverse stakeholders and the urgent need to navigate conflicting interests opens up new methods but also new spaces in which science for diplomacy can be practically tested and implemented.

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Transdisciplinary Co-creation: A Replicable Model for Collaboration Between Science and Policy

*Myriam Dunn Cavelty , Leo Eigner, Sascha Langenbach,
and Andreas Wenger*

I INTRODUCTION

Science and technology (S&T) are an integral part of modern life.¹ Due to technology's critical role in driving economic growth and bolstering national security, S&T policy has risen to the forefront of great power competition (Seidl 2024). Since science thrives on the free exchange of ideas, the movement of talent, and the sharing of resources across borders, S&T is dependent on international collaboration.

Balancing the drive for national advantage with the need for international cooperation poses a significant challenge in leveraging S&T for the common good. There is hope that science diplomacy may help. While its definition remains debated (Eigner 2023; Kaltofen and Acuto 2018a, 2018b; Lüdert 2024), science diplomacy broadly encompasses the ways in which scientific endeavors intersect with international policymaking to foster mutual understanding, address global challenges, and promote peaceful collaboration. Not least, science diplomacy is expected to play a crucial role in mitigating the disruptions caused by rapid scientific and technological advancements (see

¹“Science” is understood here as a collective term for academic work, intellectual labor, or knowledge production, not only natural sciences.

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introduction, this volume). Complex emerging issues that will likely have big consequences such as artificial intelligence, synthetic biology, or geoengineering require close collaboration between scientists and policymakers to ensure that their development and application align with societal values and global norms while not exacerbating existing inequalities or creating new forms of injustice.

But while the necessity of science diplomacy is widely acknowledged, its practical implementation toward meaningful and concrete outcomes remains a major challenge (Gore et al. 2020). A key reason lies in the fundamental differences between science and policy in terms of goals, timelines, and approaches to problem-solving (Wenger et al. 2020a). In this chapter, we describe a novel and replicable science–policy interface that navigates this intersection through *transdisciplinary co-creation*. It is built on the lessons learned from a joint research project between scientists at ETH Zürich (ETH) and practitioners at the United Nations (UN), which became the flagship project of the long-term partnership and memorandum of understanding (MoU) that was signed in October 2023.²

In what follows, we first explain the tenets of transdisciplinary co-creation, before describing the lessons learned from the partnership in more detail. We focus on three points: First, the stages of co-design, co-production, and co-implementation with their specific characteristics and difficulties. Second, we elaborate on three practical principles without which the collaboration is unlikely to succeed. Third, we identify necessary structural conditions without which a long-term collaboration is impossible to achieve. By way of conclusion, we argue that science–policy interfaces, like the transdisciplinary co-creation model underpinning the UN–ETH Partnership, should be seen as enablers of science diplomacy, because they strengthen trust and foster collaboration between researchers and policymakers and combine policy-relevant research and science-informed policies.

2 TRANSDISCIPLINARY CO-CREATION

Insights from Science and Technology Studies provide a valuable foundation for understanding the relationship between science and policy. Science and Technology Studies scholars challenge the traditional view of science as a neutral mirror of reality and argue that scientific knowledge is not purely objective (Longino 1990). Instead, Science and Technology Studies posits that knowledge is socially and materially constructed. Scientific knowledge and technological artifacts are both influenced by and contribute to social norms, values, and institutions—a dynamic prominently known as co-production (Jasanoff 2004).

²ETH Zurich is a top-ranked research university funded directly by the Swiss Confederation. It is the first public research university to have entered a formal collaboration with the UN, see press release: <https://ethz.ch/en/news-and-events/eth-news/news/2023/10/pr-closer-partnership-between-eth-zuerich-and-the-united-nations.html>

Such a worldview has significant implications for interactions at the science–policy interface, which describes an interactive space between researchers and policymakers in which relations are fostered, knowledge is shared, and policy issues are researched. First, recognizing that science and society mutually shape each other underscores the need to view them as intertwined rather than distinct entities. It highlights the importance of acknowledging their dynamic and reciprocal relationship in practice, ensuring that both scientific and societal factors are considered in decision-making processes. Second, given the integration of scientific knowledge with social, cultural, and political systems, it is crucial to blend insights from various scientific disciplines with perspectives from communities, practitioners, and policymakers.

The practice of involving a wide range of stakeholders in the development and application of knowledge is known as transdisciplinarity.³ Transdisciplinarity is “a principle of research and science, one which becomes operative wherever it is impossible to define or attempt to solve problems within the boundaries of subjects or disciplines, or where one goes beyond such definitions” (Mittelstrass 2011, 331). As a *principle*, it seeks to bridge, rather than replace, established disciplines—and at the same time extends beyond scientific disciplines by actively involving non-scientific actors in the knowledge production process (McDonald et al. 2009). The benefits are manifold: It ensures solutions are relevant, innovative, and actionable. It helps to foster collaboration, addresses ethical and social dimensions, and adapts to dynamic challenges, leading to sustainable and impactful outcomes. It also enhances learning and builds capacity across disciplines and sectors (Scholz and Steiner 2015).

However, established organizational cultures and structures in science and policy often make transdisciplinary collaborations difficult. It is therefore useful to view transdisciplinarity not only as a principle but also as a *process*. This process involves integrating two distinct approaches to knowledge production: the societal process, where practitioners tackle real-world issues, and the scientific process, where researchers investigate these issues. Each approach has its own set of rules, norms, and epistemic rationalities (Maasen and Weingart 2005).

Science is primarily driven by the pursuit of knowledge, emphasizing rigorous research, peer review, and long-term inquiry, often without immediate practical applications. By contrast, policymakers prioritize decisions that require timely, actionable information and are often under pressure to address urgent issues and respond to public and political demands. This mismatch in timelines can create frustration, as scientific research may not align with the immediate needs of the policy world (see Table 17.1). Furthermore, the language and communication styles of scientists and policymakers differ significantly; scientific work tends to be complex and nuanced, whereas policymakers seek clear, concise recommendations. Science’s commitment to independence and objectivity can also clash with the policy world’s need for pragmatic, interest-driven solutions (Wenger et al. 2020b, 233).

³ Despite extensive debate, there is no consensus around these terms (Vienni-Baptista et al. 2022).

Table 17.1 Key differences between science and policy

	<i>Science</i>	<i>Policy</i>
Mode	Pursuit of knowledge: learning	Actionable information: deciding
Question	Is it true?	Does it work?
Mechanisms	Rigorous research, peer review	Interest-driven solutions
Time horizon	Long-term	Short-term, urgent

To minimize friction between the scientific and societal spheres, we advocate for a transdisciplinary co-creation model that has three different stages. In each, scientists and practitioners engage in varying degrees, collaboratively developing solutions that bridge their distinct approaches and expertise. In the next section, this model and its characteristics is described in more detail.

3 THE UN–ETH PARTNERSHIP: A CASE STUDY

In October 2023, ETH President Joël Mesot and UN Under-Secretary-General for Policy Guy Ryder signed a MoU, committing to advance technology-enabled social innovations to address global challenges. The global focus of the UN–ETH Partnership is itself a science diplomacy marker, but the partnership is also grounded in core science diplomacy principles. As a boundary problem between science and international policymaking, science diplomacy “aims to maintain, cultivate, deepen and prolong relations” that result from the “collaborative interaction between political and scientific authority” both within and across borders (Kaltofen and Acuto 2018a, p. 11).⁴

This collaborative interaction between ETH researchers and UN practitioners occurs across three distinct modalities: joint research projects for open-ended exploration, implementation and support projects for knowledge transfer, and mutual exchanges (such as internships or fellowships) to create synergies and incubate new ideas. This set-up reflects the lessons learned from a joint research project between the Center for Security Studies (CSS) at ETH Zürich and the UN Operations and Crisis Centre (UNOCC) (Langenbach et al. 2024). Below, we outline a three-stage collaboration model, practical principles that are a necessity, as well as some evident structural constraints. Together, these elements are part of a replicable model that can help inform future science-diplomacy ventures that strive to create concrete output at the science–policy interface.

⁴The phrase “technology-enabled social innovations” was carefully chosen, because it implies that technology drives, but society *enacts* innovations. Technology thus plays a supportive rather than a deterministic role in innovation processes. For information about the partnership, visit: <https://un-eth.ethz.ch/partnership.html>

Table 17.2 Three stages of collaboration

	<i>Co-design</i>	<i>Co-production</i>	<i>Co-implementation</i>
Lead Task	Scientists and practitioners Identify use-case, research focus, and project objectives	Scientists Transformative, open-ended research	Practitioners Knowledge transfer and application to social context
Aim	Balancing science and usefulness	Scientific rules	Usefulness
Responsibility	Openness to partner goals, constraints, and institutional pressures	Practitioners respect academic freedom	Scientists respect practical considerations

A Three-Stage Model

The UN–ETH Partnership follows a transdisciplinary co-creation model with three stages—namely, co-design, co-production, and co-implementation—spanning the entire research cycle from the initial formulation of research questions to the practical application of findings (see also Mauser et al. 2013) (summarized in Table 17.2).

Co-design begins with identifying a prospective “use-case”⁵ that addresses a societal issue. This initiates a matchmaking process to assemble relevant scientists and practitioners (such as UN offices) into a team. The team then refines the use-case to clarify the research focus and objectives. The joint framing of the research question and project is crucial as well as challenging, as it must meet the needs of both epistemic groups: scientists seek intellectually stimulating research, while practitioners need practical solutions for urgent societal issues. Balancing transformational, long-term research with actionable results for short- to medium-term policy agendas is key. Additionally, operational details such as contracts, funding, and data sharing should be resolved before moving to the next stage.

During the co-design stage, scientists and practitioners collaborate on equal footing to develop a project that is both interesting and practical. This stage is crucial for understanding each other’s goals, constraints, and institutional pressures. Practitioners actively participate in shaping the research direction, technology design, and addressing ethical concerns to mitigate potential societal disruptions. This integration embodies the essence of transdisciplinarity but

⁵The term “use-case” was originally developed in the context of software engineering by Ivar Jacobson in 1987. The aim was to describe the functional requirements of a system by defining how users interact with the system to achieve specific goals. In this context, use-cases help ensure that the end-product meets the functional requirements of its intended users. We extend the use of this term to refer to an issue to which a scientific method, tool, or approach can be applied. Use-cases help researchers and stakeholders understand the practical application and relevance of research in real-world situations, demonstrating how specific methods or tools can effectively solve problems or meet needs in each context.

requires scientists to embrace this collaborative influence while practitioners avoid exploiting it for political gain. Safeguarding academic freedom is essential to maintaining scientific excellence.

The second stage in the transdisciplinary model is the *(co-)production of knowledge*. After defining the use-case, research question, and project aims, the research proceeds according to standard scientific methods and practices. During this stage, scientists lead the research, maintaining scientific quality and addressing uncertainties in their findings. Practitioners are not actively involved in the day-to-day research activities; thus, co-production is more interdisciplinary than transdisciplinary. However, practitioners play a crucial role by providing feedback as research milestones are reached and insights emerge. Their input helps test and apply findings in real-world contexts, which can refine or redirect the research to enhance its societal relevance.

The third and final stage of the co-creation model is *co-implementation*. This stage involves applying the results of the research in the form of insights, innovations, or tools, which can be conceptual, material, software, or hardware. The transition between co-production and co-implementation is fluid, with ongoing exchanges between scientists and practitioners. During co-implementation, practitioners take the lead. Unlike scientific validation, which is based on objective criteria, implementation depends on societal factors such as norms, values, and processes that practitioners are equipped to navigate. They assess the usefulness of the research results, determine how they can be implemented, and manage the practical aspects of deployment. Scientists support this process but are not experts in the societal factors influencing implementation. Practical considerations like financial, legal, and political factors also play a critical role in this stage.

Practical Principles

Transdisciplinary co-creation is a conceptual model that captures the complexities of collaborative social processes. To work, it needs to be underpinned by three practical principles: mutual trust and empathy, clearly defined roles and responsibilities, and alignment of aims. Without these principles, transdisciplinary co-creation has a higher risk of failure. Effective communication is essential throughout all stages to ensure that expectations are managed, feedback is incorporated, and any issues are addressed promptly.

First, transdisciplinary co-creation relies heavily on *mutual trust and empathy* (Harris and Lyon 2013). For scientists and practitioners to effectively collaborate across different disciplines, organizations, and epistemic communities, they must genuinely understand and appreciate each other's perspectives and experiences. This empathy is crucial for jointly framing a project, aligning diverse interests, goals, and constraints. Once the project is underway, maintaining trust is essential to prevent manipulation and ensure that influence is exercised appropriately. Achieving this balance requires continuous effort and practice. Importantly, the stakes extend beyond single projects, impacting the

broader goal of integrating transdisciplinary approaches to address urgent societal issues.

Second, clear definition and understanding of *roles and responsibilities* are crucial for all participants (Scholz 2020). While mutual trust and empathy are foundational, they must be supported by well-defined rules of engagement. The transdisciplinary co-creation model outlines when, how, and to what extent each participant can influence the project. Legal protections, such as academic freedom, ensure that scientists can conduct research without political interference. Practitioners must respect this freedom, while scientists should value and integrate the expertise of practitioners, especially in the co-design and co-implementation stages.

Third, continuous *alignment of aims* is essential (Horcea-Milcu et al. 2022). On an operational level, scientists must see the research as both meaningful and intellectually challenging, with potential for impact, while practitioners need to be confident that the research will yield practical insights and tools for addressing immediate issues. On a strategic level, the long-term goals of the organizations involved must also align. For instance, the UN's focus on digital transformation matched ETH's ambition to promote policy-relevant research and establish its school of public policy.⁶ The synergy between these goals provided high-level support, facilitated access to key individuals, addressed operational concerns, and accelerated progress.

Necessary Conditions

The three stages of transdisciplinary co-creation and the practical principles are important features of this science–policy interface. However, we also noticed three additional, structural challenges.

First, effective *matchmaking* at the outset of transdisciplinary co-creation is crucial for initiating and launching collaborations. This process often requires guidance by facilitators versed in transdisciplinary co-creation and its challenges, as misunderstandings and frustration between scientists and policymakers can lead to mistrust, as seen during the Covid-19 pandemic (cf. Thorén and Gerlee 2024). To provide this guidance, we launched a new instrument within the Partnership: the UN–ETH Incubator. This ETH-led program sources specific, real-world use cases from UN offices, identifies relevant research groups at ETH Zurich, and initiates a matchmaking process. The aim of this process is for UN offices and ETH research groups to familiarize themselves with each other's mandate and align their needs, interests, and aims around the use case before embarking on the first stage of the transdisciplinary co-creation model.

⁶The Albert Einstein School of Public Policy was inaugurated in October 2025 and is an interdisciplinary centre at ETH Zurich that combines public policy, science and technology to address societal challenges. The new centre is the flagship programme of ETH Zurich in its ambition to promote policy-relevant research and strengthen the science-policy interface. From 2026, the centre manages the UN-ETH Partnership.

In order to promote transdisciplinarity at the science–policy interface, it is important to develop mechanisms like the Incubator.

Second, securing *funding* for transdisciplinary co-creation models is a challenge. Traditional R&D funding is often concentrated in established disciplines, particularly in STEM fields, leaving transdisciplinary projects reliant on discipline-based funding. Since co-creation takes time, especially during the early co-design stage, and requires significant human resources before tangible results are produced, this creates an imbalance. Larger, well-funded research chairs can manage the delay, while smaller, less resourced chairs struggle. To support smaller institutions in collaborations like the UN–ETH Partnership, alternative funding mechanisms, like start-up funds, are needed to kick-start these efforts.

While the first two challenges can be managed, the third is inherent and can only be acknowledged. Science and policy operate on *different timelines*: research is often open-ended and long-term, whereas policy is focused on immediate, problem-oriented outcomes influenced by political and bureaucratic processes. The UN–ETH Partnership addresses this structural issue with the modalities of cooperation that provide science and policy partners with options that accommodate their differences and aligns their common goals. In this context, it is important to note that substantial resources and expertise are required not only in the development of solutions but also in their operation (Langenbach et al. 2024). This also means that international organizations must expand their internal resources and hire staff with degrees in STEM if they are to take advantage of modern scientific solutions.

4 CONCLUSION: ENABLING SCIENCE DIPLOMACY

Science diplomacy must be operationalized to realize its potential for enhancing international relations and addressing global challenges. Science–policy interfaces, such as the transdisciplinary co-creation model we described in this chapter, serve as concrete mechanisms of science diplomacy by fostering engagement and collaboration between researchers and policymakers. These interfaces act not only as *enablers* of science diplomacy but as *examples* of it in action.

Science–policy interfaces are particularly critical in this era of rapid technological disruption. As scientific discoveries and technological breakthroughs accelerate, policymakers must enhance their scientific literacy to understand disruptive trends before they escalate. This would enable them to develop proactive policies that maximize benefits while mitigating risks. Concurrently, researchers need to deepen their understanding of policy issues and processes to better support practitioners and decision-makers. The implications for science diplomacy are evident: Greater investment in science–policy interfaces would have better positioned governments and multinational organizations to address pressing challenges, such as AI governance and future pandemics.

The transdisciplinary co-creation model emerged from a science diplomacy initiative between the UN and ETH Zurich. However, the foundational principles of this partnership are not unique and can be replicated across diverse scales and contexts. While our case study highlights a collaboration between the world's largest intergovernmental organization and a leading technical university, the principles of transdisciplinary co-creation are adaptable to partnerships between any research-performing and policy-performing organizations. These could include state ministries, private businesses, charitable foundations, and a wide range of non-governmental organizations.⁷

Establishing effective collaborations at the science-policy interface comes with significant challenges. While the ultimate goal of transdisciplinarity is to achieve social impact, it also aims to foster interactions across and beyond scientific disciplines and facilitate reciprocal knowledge transfer between science and society. Bridging the divide between science as the “active” producer of knowledge and society as the “passive” consumer requires a fundamental rethinking of current systems and a commitment to more inclusive and collaborative approaches. Mechanisms like the UN-ETH Partnership demonstrate how transdisciplinary co-creation can be leveraged to tackle complex global challenges. By adopting similar models, we can better realize the transformative potential of science diplomacy.

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⁷For instance, ETH Zurich has a similar partnership with the International Committee of the Red Cross (ICRC). Engineering Humanitarian Action is an initiative launched in 2020 by the ICRC, ETH Zurich, and EPFL. The initiative develops, tests, and scales innovations that help address humanitarian challenges.

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Applied Sciences for Research and Practice

Ekkehard Strauss 

I ROLE OF UNIVERSITIES OF APPLIED SCIENCES IN THE GERMAN EDUCATION SYSTEM

Alongside universities and art colleges, universities of applied sciences (UAS) are the primary academic institutions for teaching and research in Germany. This type of university, introduced in 1968, was intended to provide targeted academic training with a high degree of practical relevance, particularly in technical and business administration degree programs and in social work. Over the past 50 years, the number of UAS increased enormously as a result of German reunification and new foundations. A reorientation of content and structure of UAS following the conversion of all degrees to Bachelor and Master, new legally defined tasks such as the obligation to conduct applied research, the promotion of knowledge transfer, the increasing importance of lifelong academic training, and improved opportunities for doctoral studies were important cornerstones in the development of UAS as unique academic institutions (Hüther and Krücken 2018).

In line with their history, UAS continue to place particular emphasis on the applicability of their teaching and research to specific professions. The focus of the training is on graduates' employability within the labour market. As a consequence, UAS maintain close links with public administration and private companies within their local and regional environment. These links are reflected in dual study programs, the development of degree programs in cooperation with future employers, the placement of students as interns, and application-related, often joint, research, including in the context of B.A. and M.A. theses (Ertl 2020).

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Due to their role in the education system, UAS are important actors in science diplomacy supporting economic, social, and technological change through applied research, innovative partnerships, and policy engagement, closely connected with business, public administration, and the judiciary.

2 CHALLENGES IN RESEARCH AND TEACHING AT UAS IN AN ERA OF TECHNOLOGICAL DISRUPTIONS

Due to the broadening of the concept of national security since the beginning of the 2000s, it encompasses activities, which previously belonged to business areas such as procurement and supply chains, IT and data processing, or research and development. Private companies and public administration have been challenged constantly to react quickly and efficiently to risks related to technological change. The application-oriented research and teaching by UAS can support business and public administration particularly well in mastering these challenges through international exchange and collaboration.

The Berlin School of Economics and Law (BSEL) for example, offers 25 dual study programs mainly in economics, business administration, and security management, in cooperation with 700 private companies, study programs for the Berlin police, and training of judicial officers for the judiciary of the State of Berlin. Many courses are carried out using collaborative online learning methods across countries, time zones, and university systems with teachers and students from 178 partner universities to enhance international experience at home. In order to increase the applicability of research, BSEL established 17 interdisciplinary research institutes, including for public and private security, for the transfer between science and practice, and for sustainability, in which an exchange between science and practice at the international level is promoted and the application of research results critically scrutinized.

Technological disruptions form the main focus of various projects, for example, of the Research Institute for Public and Private Security (FÖPS Berlin). Currently, FÖPS is working with public and private information technology institutions on the legal, ethical, and social requirements for the development and police use of an AI-supported detection program for deep-fakes used to spread disinformation, but also to manipulate digital proof of identity.

While, so far, legal research on AI-based applications in the police focused on face, speaker and object recognition as well as text analysis, in another project, FÖPS contributes to the interdisciplinary concretization and technical implementation of a catalogue that formulates ethical and legal requirements and limits for the development and use of AI processes in police applications. Other projects explored the defence against drones by the police at public gatherings and the general protection of people and property potentially endangered by drones, and a technical solution with which fingerprints, facial images, and official documents can be quickly captured, checked for

authenticity, and compared by security managers on a mobile device (FÖPS Berlin [n.d.](#)). Science diplomacy has been indispensable in the realisation of these projects.

3 SCIENCE DIPLOMACY OF UAS

Science diplomacy is understood differently by different actors, e.g., diplomats, science actors, or NGOs (Turekian et al. [2015](#); Ruffini [2017](#)). The growing literature and case studies did not lead to an agreed concept or theory (Ruffini [2020](#)). Science diplomacy is more than political support for scientific cooperation between institutions from different countries or regions. According to the Royal Society's often used definition, the dimensions of science diplomacy include diplomatic support for science projects, scientific policy advice, and the use of science to achieve diplomatic goals (Royal Society and AAAS [2010](#); Gluckman et al. [2017](#)). However, science diplomacy can be less than the support of diplomatic processes through science, as the interactions between the two disciplines is researched insufficiently. In addition, the analysis to date is focused mainly on specific technical and natural science projects under the leadership of Western countries, in particular, the United States (Campbell [2015](#); Vafai and Lansey [2018](#)).

As illustrated by the examples above, for UAS, science diplomacy should be understood as an umbrella term for contributions to response strategies to overcome global challenges in an era of technological disruption. Science diplomacy is a change of perspective from research and science as a separate field of occupation towards a broader perspective on the global impact of its processes and results, possibilities to overcome inequalities, and the international political environment for its application. Science diplomacy is not a separate area of activities with clear delimitations from research, teaching, or administrative tasks, for example, admission criteria or scholarships for foreign students. In this understanding, science diplomacy of UAS clearly exceeds previous activities in science communication and science cooperation.

The SDGs are a frequent point of reference for the international significance of science for diplomacy. They are intended to express the dynamics of change in the areas of climate, health, migration, and security (United Nations [2023](#)). In fact, the recently adopted UN Pact for the future identified them as the global solution for the most serious and pressing international challenges (United Nations [2024](#)). They are grounded in international human rights obligations and require dialogue and mutual trust for their implementation.

The efforts of governments to implement the SDGs led to raising demand of sustainability policies for different sectors, based on scientific research. Some of these policies even translated into normative standards, e.g., national and regional due diligence legislation. UAS are particularly qualified to respond to the demand of state and business actors to develop research-based solutions and evaluate the implementation of new normative standards.

4 CONTRIBUTIONS OF UAS TO ADDRESS TECHNOLOGICAL DISRUPTION THROUGH SCIENCE DIPLOMACY

Based on this understanding, it should be acknowledged that UAS are already active in science diplomacy without necessarily having an awareness of or a concept for it. Existing policy papers at the national and international level do not adequately address the special opportunities offered by UAS though (Auswärtiges Amt 2020; DAAD 2022, 2024; Riordan and Torres Jarrín 2020; Piaget et al. 2023).

The particular contribution of UAS to the various aspects of science diplomacy should be considered in particular in the field of economics, law, and other social sciences and their respective link to security. In a multipolar world in which states and political groups within states are competing for influence, the scientific basis and related traditional norms are instrumentalized increasingly for conflicts at the local, national, and international level. In this regard, the cooperation in research in natural science or engineering is often less controversial than in social sciences or law (Andresen 2014). Ultimately, the solution to technological disruptions lies in an international consensus on the applicable rules and standards.

From an applied research perspective, the challenges of different societies, regardless of their political system, with regard to, e.g., the implementation of climate change policy, the fight against terrorism and organised crime, poverty and social inequality, or the future prospects of young people show major parallels. The more sensitive related scientific findings may be for their proximity to contested norms and values, the more important is the emphasis of their applicability for responding to actual common challenges and an interdisciplinary approach. Science diplomacy of UAS is not aimed at substantial changes to political systems, but at building trust among international partners through transparency, scientific integrity, and respect for the mutual interest in successful transfer of findings. Science automatically conveys certain values, including equality, respect for cultural differences, and scientific freedom, which are also part of the international human rights agenda. Thus, international networks of science partners at the local level can counter the political polarisation at the international level with positive examples of successful cooperation within a parallel global order for joint decision-making based on data and evidence.

However, as part of a strategy for a value-based foreign policy, science diplomacy of UAS must go beyond short-term diplomatic goals of national foreign policy. Thus, UAS must be critical of the adoption of sanctions limiting science cooperation at the local level as part of state diplomacy, e.g., by questioning the restriction of cooperation with universities in Russia following the invasion of Ukraine (Dobko 2024). As demonstrated by the above examples, UASs have particular experience in balancing academic freedom and national policy interests. While the interests of the specific project partners are protected, research results can be incorporated into

other activities of science diplomacy related to teaching, research, and policy engagement.

UAS need to integrate explicit references to the SDGs throughout their activities in order to increase the relevance of their research findings for science diplomacy. Ultimately, the realization of SDGs is implemented at the local level and measured against quantitative and qualitative indicators. As illustrated by the examples above, UAS, through practical research in cooperation with state and non-state stakeholders, can make a unique contribution to sharing experience and communicating challenges related to the implementation of specific SDGs, and demonstrate the benefits of applied sciences at the local level. Ultimately, UAS should become part of global and national reporting systems on SDG implementation.

In addition, UAS should play a greater role in international relations directly, beyond their scientific cooperation with private business and state actors. Over the past years, international relations witnessed the increasing relevance of additional stakeholders in public diplomacy and international norm creation and implementation such as private business, NGOs, and civil society (Lüdert 2023). Many UAS partners are themselves direct actors in international policy processes and can multiply the impact of applied research. Science diplomacy of UAS should include a visible contribution to existing structures of the UN for knowledge and norm production and aim at participating in the UN academic impact, the Secretary-General's Science Council or other elements of a "third UN" (Carayannis and Weiss 2021), e.g. through the UAS7 initiative (UAS7 n.d.). However, science diplomacy of UAS should not be limited by these new institutions and processes but should develop and implement their own interdisciplinary and decentralised political processes to overcome global challenges at the local level.

As a consequence, UAS need to integrate UN research as part of science diplomacy. UN related training and research should be concerned with the analysis of relevant decision-making processes, i.e., the structures, legitimacy, efficiency, and communication challenges of the organization itself (Volger 2023). In addition, the role of science in decision-making processes needs its own scientific analysis in order to support member-states in their science diplomacy initiatives within the UN (Ambrus et al. 2014; Lüdert 2024; Permanent Mission of Switzerland to the United Nations 2024).

5 CONCLUSIONS

UAS need to conceptualize and communicate their unique contribution to science in and science for diplomacy, individually and through existing associations at the national and international level. They respond daily to technological disruption through applied research and teaching and should be more active in shaping solutions through science diplomacy. On this basis, UAS should be included systematically in national and international fora for science diplomacy and SDG implementation. Donors like the EU, UN programmes,

funds and agencies, and national governments should encourage the specific contributions of UAS to science diplomacy strategically through their funding decisions and modalities of civil society participation.

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Technological Advancement and the Mission of Health Professions: Students as Stakeholders for Science Diplomacy—The International Collaboration and Exchange Program (ICEP GLOBAL)

Anette Wu 

I INTRODUCTION

In a world that has just emerged from one of the most severe global public health crises in modern history, we find ourselves confronted with escalating geopolitical conflicts, climate change, population migration, and deep societal divisions. These challenges require a holistic approach that recognizes the vital role of the next generation of professionals in shaping our collective future.

Health professionals and physicians are represented ubiquitously worldwide, comprising a large number of individuals who share the values of dedication to public service and humanitarian work for the health of all people. In most societies these professionals hold respected and influential positions. Many are increasingly involved in civic engagement. Although globally the WHO supports the medical profession, to date, very few groups have engaged young trainees in medicine to advocate for science diplomacy intentionally.

Internationalization of Medical Education (IoME) is a form of global cross-border teaching and learning (Wu et al. 2022a). IoME only recently presented as part of academia (Wu et al. 2022a) to support student education and

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cultural understanding. There are different motivations and processes to engage institutions and students in IoME (Wu 2022a; Wu et al. 2020b). A lesser known and impactful motivation is based on what is called the “Liberal Model” (Wu and de Wit 2022). This model is based on the mission of intentionally providing students with skills to work collaboratively and work transcending physical borders—particularly cultural competency, communication, collaborative global problem-solving skills, mutual understanding, and the promotion of world peace focusing on the creation of an international community (Wu and de Wit 2022).

How is Internationalization of Medical Education put in practice these days? A current focus has been on student mobility, with emphasis on immersive clinical exchanges. Virtual experience and the use of technology play a minor to no role currently (Wu et al. 2020b, 2021). Presented below is a case of an online global multilateral exchange program that was initiated years prior to the COVID-19 pandemic, focusing on science diplomacy as its motivation and utilizing technology as a vehicle for IoME.

2 THE PROGRAM

The International Collaboration and Exchange Program (ICEP GLOBAL) was founded in 2014 by a faculty member at Columbia University, New York City, USA, and attracts about 750 students from around the world annually.

Long before the pandemic, ICEP GLOBAL began as an innovative virtual program to foster global collaboration and international understanding between medical and health profession students with leadership aspirations. The program offers a two-semester virtual co-curriculum that includes synchronous and asynchronous activities including faculty lectures, immersive break out rooms, small group projects, and online chats. Virtual bonding as baseline for community building provided equity and sustainability for the Internationalization of Medical Education. Students, regardless of their nationality and region, engage in global discussions with each other and attend office hours online with expert professors from around the world. The online experiences are enhanced with optional hybrid global student conferences, research, and immersive travel exchanges.

Sustainability is achieved via post program online hybrid offerings: long-term continuation in regional ICEP GLOBAL chapters and societies, virtual shared interest groups, online chats, postdoctoral exchanges, and continuing education lectures online.

3 ANALYSIS OF THE PROGRAM

The program has unique features that support science diplomacy while taking advantage of modern technology.

Intentional Science Diplomacy

Unlike other programs that often focus on social equity in health care or enrichment of students' competitive portfolio, this program's mission is primarily supporting global collaboration via the "Liberal Model" in Internationalization of Medical Education with learning objectives covering collaborative global problem solving, cultural competency, mutual respect, tolerance, and understanding (Wu and de Wit 2022). Science diplomacy is not a byproduct but an intentional mission of the program.

Online Immersion and Technology

The learning objectives of the program are built on interactive components and are heavily dependent on the use of modern technology. Long before the COVID-19 pandemic, the program utilized video conferencing as a medium for virtual exchanges starting with platforms such as Skype® and Go-to-Meeting®, subsequently utilizing Zoom®. When COVID-19 locked down physical exchanges in 2020, the program had already built a platform that required no modification thus ensuring continuation of international experiences for students during a phase of isolation (Wu et al. 2020c). The interactive and immersive cultural component where students exchange their life experiences in real-time videos and chats is utilizing and dependent on programs like Slack®, WhatsApp®, Facetime®, or Discord® but also social media such as Instagram®. Knowing how one's counterpart lives, what they eat, what they see and experience daily activities through shared real-time videos fosters bonding and cultural understanding. The immersive interactive videos would have not been possible without the use of advancement in technology.

Involvement of the Health Professions in Science Diplomacy

Uniquely, the focus is on the health profession. While medicine is always built on collaboration, the sole target on medical professionals is bringing in a profession whose focus is public service and humanitarian work. Students are selected for their leadership potential in health care as future influential leaders of society. The impact of participants on the future of science diplomacy will be multiplied as students graduate and positively affect their home countries as agents of social change.

Targeting the Youngest, Shared Interests, and a Common Ground

ICEP GLOBAL focuses on very junior students (the majority in their first year of study), with many of them in their late teens and early twenties. Students come together during their formative years and are provided with a sense of global community and a diverse global network as global citizen physicians.

Uniquely, the program was initiated by anatomy professors—a profession that is ubiquitously present in all medical schools to which all medical students are exposed to. Involving anatomists in science diplomacy has the potential to reach all students globally.

4 LEARNING OBJECTIVES AND SCIENCE DIPLOMACY IN ACTION

In order to foster mutual understanding through ambassadors of peace online, the program's learning objectives focus on understanding of other countries and cultures, while learning about extracurricular topics in the areas of global health, public health, health policy, history of medicine, etc. (Wu and Preker 2023).

The program students learn to be tolerant, open minded, and practice debates and difficult conversations. While preconceived political opinions cannot be changed, open listening skills supported important learning objectives such as communication, cultural competency, tolerance, and respect.

5 MULTILATERALISM, DIVERSITY, AND SUSTAINABILITY

The diversity of the student body extends beyond the countries of the ICEP GLOBAL partners. Many are international students (e.g., Middle East, Southeast Asia, South America, etc.) and provide a cultural and spiritual diversity, and a basis for multi-lateral learning and understanding the context of medicine in different parts of the world. Exposure to such diversity is crucial for forming a global mindset.

Unlike many exchange programs that have a defined end, ICEP GLOBAL's sustainability is achieved via continuation in regional ICEP GLOBAL chapters, shared interest groups, and a joint newsletter. Student and alumni ICEP GLOBAL chapters arrange for regional meetings, online sessions, and post program visits. Post program graduate exchanges ensure that students will always feel that they are part of a welcoming global community.

6 OUTCOMES

Endorsements from students reflect the impact of the program on their ability to think globally and collectively about health care going forward. The above is combined with the acquisition of competencies in diplomatic skills, cultural competency, and communication skills, leading to respectful global understanding (Wu et al. 2020a, 2020c, 2022b; Lam et al. 2023; Vigoda et al. 2022). ICEP has been proven to create long-lasting friendships that transition into collegial professionalism and collaboration throughout the participants' careers (Fig. 19.1).

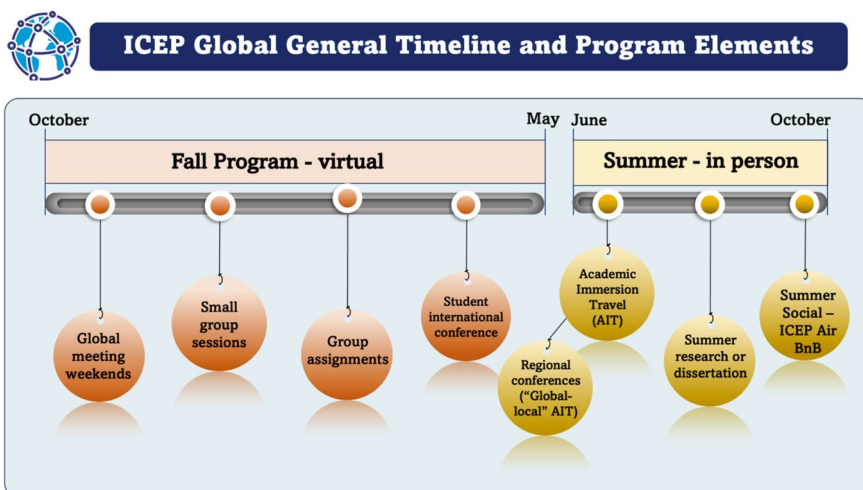


Fig. 19.1 International Collaboration and Exchange Program (ICEP GLOBAL).
Source: Authors own Conference Visual

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Art-Science as a New Frontier for Diplomatic Thinking and Praxis

Nikita Lin 

1 INTRODUCTION TO ART-SCIENCE DIPLOMACY

Historically, art-science began as a grassroots initiative: self-organized scientists, engineers, and artists worked together to promote new forms of knowledge and education that emphasize hands-on, intuitive experience. As predecessors, one can point to the internationally acclaimed journal *Leonardo*, established in 1968 by the astronautical pioneer and artist Frank Malina, and The International Society for the Arts, Sciences and Technology, formed in 1980 (*Leonardo* n.d.). In the twenty-first century, art-science has evolved into different trajectories and bifurcations. One of these trajectories moves in the direction of policymaking.

In the policy framework of the European Union, art-science diplomacy has derived from the broader strategy of cultural, science, and innovation diplomacy. In 2015, a call was launched by the European Union's Horizon 2020 research and innovation program under the topic "European cultural and science diplomacy: Exploiting the potential of culture and science in the EU's external relations" (European Commission 2023). Cultural diplomacy, which "can be (co-)delivered by actors in a 'bottom up' manner," is of increasing interest to European policymakers at a time when other major global players "are stepping up their public diplomacy efforts around cultural issues, including science and education" (European Commission 2023). Subsequently, in 2016, art-science entered the horizon of EU policymakers when the Joint

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Research Center (JRC) launched “SciArt: Science Art Society,” a project linking art and science to policymaking and society (European Commission [n.d.](#)).

Swissnex, a global network initiated by Swiss science diplomats, has been promoting interdisciplinary and cross-border collaboration globally since its early days. The 1990s tech boom in the Silicon Valley sparked innovative thinking and practice among the Swiss diplomats. In 1997, Switzerland created the Science and Technology Counselor position in San Francisco. Swissnex was subsequently conceived to “bridge higher education with innovation, science with art, and technology with public diplomacy” (Simm [2021](#)). Swissnex’s arts and science platform nurtures a global community of arts professionals and institutions working at the arts, research, innovation, and technology interface (swissnex [n.d.-a](#)). The art-science platform at swissnex in China was launched in 2008. It facilitates Sino-Swiss cooperation and exchanges through art exhibitions, public lectures, and art-science dialogues. In the following, we will present an example of art-science diplomacy from swissnex in China: the exhibition *Cosmos Archaeology*.

2 CASE STUDY: COSMOS ARCHAEOLOGY

Between 2020 and 2022, the research teams from EPFL’s Laboratory for Experimental Museology (eM+), Laboratory of Astrophysics (LASTRO), and EPFL Pavilions collaborated to create an art-science exhibition called *Cosmos Archaeology: Explorations in Time and Space* (EPFL Pavilions [n.d.](#)). The eM+ research team, led by EPFL Professor Sarah Kenderdine, is specialized in computational museology, which combines machine intelligence, data curation, visualization, and immersive public interactions to facilitate engagement with cultural heritage. For two years, the team worked to find ways to translate imperceptible cosmological data into perceptible visual experiences for the public. They developed a series of customized immersive interfaces specifically for astrophysical data, such as the “sky mapping” data drawn from optical sky survey missions like the Sloan Digital Sky Survey (SDSS). They developed forms of interactive data simulation and visualization, immersive projections, 3D films, and augmented reality that in 2022 successfully presented “what is cooking in the labs” to the research community, policymakers, and the public. In the exhibition, scientific data and visualizations are intertwined with cultural imaginations, stories, and philosophical contemplations. Visitors could experience, imagine, and reflect on scientific explorations of the universe in an intuitive way.

In 2024, the exhibition traveled to the Shanghai Astronomy Museum in China. This Chinese version of the exhibition was given a new title: *Cosmos Archaeology: Exploring the Universe Through Art & Science*, highlighting art and science collaboration (swissnex [n.d.-b](#)). In this custom version, a Chinese curator was invited to bring in artists and exhibits from recent achievements in space science in Chinese institutes. These new pieces from the Chinese side include the Multiplexed Survey Telescope (MUST) from Tsinghua University

and the Square Kilometre Array (SKA) project, led by the Shanghai Astronomical Observatory. The exhibition was on view from May through November. Despite taking two hours to get to the museum from the city by public transport, the exhibition enjoyed great popularity and attracted over 73,000 visitors (Swissnex [n.d.-c](#)).

During the exhibition, swissnex and local partners organized public events and workshops on topics related to the exhibition. These programs included guided tours with the curators, an opening symposium, a film screening, and a hands-on workshop on computational museology. One of the core issues of the exhibition, according to the curator Sarah Kenderdine, concerned space sustainability. In Switzerland, an EPFL startup has been looking at cleaning up space junk. The curatorial team brought in artists who had been dealing with the theme of space junk into the process of co-creating the exhibition. Through a variety of public engagement activities, audiences in Shanghai were invited to join discussions on the synergies between art and science, as well as issues in space that concern the future of humanity, such as increasing space debris. These activities offer local citizens a chance to see, experience, and participate in the discussions and debates of “what is cooking in the labs,” what are the problems out of the labs, and what can individuals and societies do about it. “[The] way that the cultural imaginary works in the public domain was really important,” emphasized Sarah Kenderdine in an interview (swissnex [2024](#)).

3 OPPORTUNITIES AND CHALLENGES

Swissnex in China played a crucial role in the success of the exhibition *Cosmos Archaeology*. In parallel, a research collaboration on the Multiplexed Survey Telescope (MUST) project was negotiated between the EPFL and Tsinghua University. The agreement was signed in Beijing during the visit of the Federal Councilor and Head of the Federal Department of Economic Affairs, Education, and Research of Switzerland (swissnex [n.d.-c](#)).

Swissnex in China was the initiator of the exhibition in Shanghai. According to Cissy Yiwen Sun, Head of Academia and Arts (formerly Head of Art-Science) at swissnex in China, the idea began to take shape in the winter of 2022 when she saw a film produced by the EPFL team. She and her team in Shanghai then reached out to the Shanghai Astronomy Museum, which responded with interest and enthusiasm. “Timing was important,” recalled Sun, “The museum was opened one year ago, and they were in search of directions. What the EPFL team has been doing is future oriented. Their project presents cutting-edge technologies and innovation. These are attractive elements for our local partners” (Sun [2024](#)). As for the Swiss team, the newly built museum and the large audience in the local scene meant a good opportunity to increase their international visibility. With swissnex’s expertise in international cooperation, the partnership was expanded to bring in more stakeholders, including researchers, artists, and cultural investors. Impressed by the success of the exhibition in Shanghai, other Chinese institutes started contacting swissnex in China for

collaboration. It has been announced that the show will travel to Guangzhou and Beijing in 2025.

However, these opportunities were also met with challenges. The first challenge came with censorship and bureaucracy on the Chinese side. To deal with these issues, swissnex in China relies on the special expertise of its “local anchors,” employees, and partners with profound local experience and knowledge. Strong local anchors provide creative solutions for difficult issues with local authorities. For Cissy Yiwen Sun, who has held her position at swissnex in China since 2009, the constant challenge in her work remains to coordinate and communicate different interests, expectations, values, and systems which lack transparency. For example, the partnership with the Shanghai Astronomy Museum, a state-run institution, had involved extremely time-consuming negotiations. It was also a challenge to explain to the Chinese research institutions and scientists and to make them understand art-science as a co-creation process. “For most of these institutions, it was the first time they opened their doors to artists,” said the Chinese curator Iris Long (swissnex 2024). The second challenge in the *Cosmology Archaeology* exhibition concerned the technical and financial aspects of its production. It was an expensive high-tech exhibition. Luckily, through Tsinghua University, the swissnex team found a Chinese company who covered the production cost. Meanwhile, the technical complexity of the set-up and maintenance of the exhibits demanded close cooperation between the Chinese and Swiss teams.

The diplomatic implication of these opportunities and challenges is both local and global. It is first and foremost reflected in the current geopolitical environment. “The chance to bring forth a fruitful collaboration would be higher when we choose an area of scientific research such as astronomy, because space science concerns the future of humanity as a whole,” said Cissy Yiwen Sun (2024). Her observations from inside China reflect how current geopolitical tensions impact cultural exchange as well as scientific collaboration between China and Switzerland. “With the US moving to hinder China’s access to advanced technology and the European Union aligning more closely with Washington, Swiss companies in particular risk getting caught in the middle” (Stamm 2024). While in China the cultural sector is facing increased censorship, on the Swiss side, it is the high-tech companies that are having a hard time. Nevertheless, the Swiss science diplomats see the cultural industry as a strategic sector to boost competitiveness and sustainable economic growth in both Switzerland and China. It is thus timely to combine art with science as a soft power to strengthen exchange and collaboration between the two countries despite the current geopolitical tensions. There are certainly many sensitive issues that the Chinese hesitate to touch. Yet, it is important to keep the information flow open by arranging regular personal meetings and exchanges. “They [Swiss scientists, researchers, artists, and entrepreneurs] must come to China to see and experience for themselves.” According to Sun (2024), that is how trust could be built among civil actors and societies across national borders.

4 ART-SCIENCE AND PUBLIC TRUST IN SCIENCE

The Diplomatic Service of the European Union has identified a key challenge in current science and diplomacy. While science, technology, and innovation are important in tackling global challenges, the decline in public trust in science has undermined democracy and multilateralism (European External Action Service 2022). This EU message resonates in Geneva. In 2015, the Swiss Minister of Foreign Affairs initiated an international working group called “Geneva+” that in 2018 proposed a new type of science and diplomacy organization, recognizing that local players are “increasingly influencing global issues and thus becoming geopolitical forces in their own right.” In 2019, the Swiss and Geneva governments founded the Geneva Science and Diplomacy Anticipator (GESDA) “to leverage the anticipative power of science with diplomacy organizations and citizens working in Geneva and around the world.” In many ways, it seems to suggest a participatory model of science and diplomacy, “bringing together citizens ... and impact-oriented communities in order to form creative coalitions” (Geneva Science and Diplomacy Anticipator n.d.).

GESDA’s top-down vision faces challenges when it comes to grassroots implementation. In a complementary manner, the *Cosmos Archaeology* exhibition provides a solid example of implementing this new vision. Through a bottom-up approach, the art-science exhibition has the potential to form multilateral, cross-disciplinary creative coalitions. The exhibition can travel to different countries and forge in-depth connections with local stakeholders to jointly address the concerns of space sustainability. It can thus provide a platform for global citizens to exchange knowledge and opinions and build consensus; they can propose creative solutions to solve the world’s problems. To achieve this, we recommend that culture and science diplomats jointly form a global art-science nexus to coordinate, communicate, and share experiences, resources, and expertise. Germany’s Goethe-Institute, for example, has been promoting art-science activities globally over the past decade, and its recent Quantum Studio artist residency has run successfully in Asia, South Africa, and Europe. When these (inter)national art-science platforms are networked under common global diplomatic goals, individual actors and institutions can play a stronger role in creating multilateral dialogue and building trust in science across different societies.

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PART III

Frontier Domains and Contested
Governance Arenas



Transformational Technology Leaders, Game Theory, and Science Diplomacy in the Age of Artificial Intelligence

Marcus D. Weller

1 SCIENCE DIPLOMACY IN THE AGE OF AI

Artificial Intelligence (AI) is rapidly reshaping economies, societies, and geopolitical landscapes (Brynjolfsson and McAfee 2014; Schwab 2016; Tegmark 2017), presenting a critical juncture for international relations. This technological revolution demands innovative approaches to AI governance and international cooperation. The intersection of AI and science diplomacy offers both unprecedented opportunities and profound challenges, requiring leadership that balances AI innovation with inclusivity and ethical governance (Bostrom 2014; UNESCO 2021). This chapter aims to explore how science diplomacy, particularly in light of its evolving definition, serves as a uniquely capable tool for managing AI's disruptive potential. The age of AI calls for adapting traditional diplomatic frameworks to new technological paradigms. Science diplomacy, as defined by the Royal Society and the AAAS (2010), encompasses three key pillars: “science for diplomacy” (using scientific advice to inform diplomatic objectives), “diplomacy for science” (facilitating international scientific collaboration), and “science in diplomacy” (using scientific collaborations to improve international relations). The AAAS’s recent reflections in “15 Years On” highlight a need to adjust these pillars to better address rapid technological advancements and accelerating scientific progress (AAAS 2024). In the context of AI, these pillars are essential for navigating the complex interplay of national interests and global responsibilities.

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AI's disruptive potential evokes a duality of emotions: hope for a future enriched by technological breakthroughs, and apprehension over the societal upheavals it may cause. While AI may hold the key to unlocking humanity's potential (Tegmark 2017), unchecked AI development also poses risks, including the amplification of inequality and the erosion of democratic coalitions (Bostrom 2014, 88–94; Brynjolfsson and McAfee 2014, 165–190). Science diplomacy provides a powerful mechanism to manage this duality, fostering international dialog and cooperation to mitigate risks while maximizing benefits. Historically, science diplomacy has bridged nations, fostering collaboration even amidst geopolitical tensions. The 1960s space race, spearheaded by President John F. Kennedy, exemplifies how science and technology can inspire both cooperation and competition. Kennedy's vision for lunar exploration galvanized the United States and spurred global advancements in science, technology, and international partnerships (Logsdon 2010; Krige et al. 2013). His 1962 "We choose to go to the Moon" speech set the stage for international collaboration on an unprecedented scale, beginning with the Apollo-Soyuz Test Project, a clear example of "science in diplomacy" that bridged Cold War divides. Similar to space exploration, Artificial Intelligence provides a new potential catalyst for global collaboration, provided we have visionary transformational leaders who can inspire collaboration toward a common future. This chapter will explore how these leaders can leverage science diplomacy to navigate the complex challenges and opportunities presented by AI, drawing upon both historical examples and contemporary insights to illuminate a path forward.

2 INNOVATIVE AI TOOLS FOR MODERN SCIENCE DIPLOMACY

Innovation is a foundational element of the US GDP and a crucial area for the application of AI globally. AI serves as a powerful instrument for innovation within science diplomacy by expediting the translation of scientific findings into strategic action. The scientific community is only now beginning to grasp the transformative impact of AI-driven research and development. Large Language Models (LLMs), with their ability to rapidly analyze and synthesize vast amounts of information, can uncover patterns beyond the reach of individual researchers. This is particularly crucial given the exponential growth of scientific literature, which often forces scientists into increasingly specialized niches, making cross-disciplinary collaboration and breakthroughs less likely. LLMs resolve this by synthesizing knowledge across diverse disciplines, sometimes uncovering hidden connections within the data (Luo et al. 2024). Beyond analyzing prior research, AI can also predict new discoveries, illuminating new research and development directions and accelerating technological progress. Recent research demonstrates that LLMs exceed human scientists in their ability to predict future neuroscience study results in studies that have yet to be conducted (Luo et al. 2024).

Indeed, organizations and institutions are already leveraging LLMs to unlock new discoveries. For example, DeepMind builds powerful AI models

that learn from vast data sets to identify patterns and make predictions in complex systems (O’Leary 2024). These models, trained on data like protein sequences or physical laws, are then applied to new problems, enabling them to predict protein structures, design new materials, or optimize complex processes like plasma control in fusion reactors. Demis Hassabis and John Jumper were awarded the 2024 Nobel Prize in Chemistry for their work on AlphaFold, an AI system that can predict the 3D structure of proteins (O’Leary 2024). Similarly, DeepInvent uses deep learning to reveal hidden relationships in scientific and patent data to generate new inventions (Deepinvent 2024). It identifies latent knowledge patterns across diverse scientific literature and patent databases to synthesize new intellectual property and then enhances these ideas using cross-disciplinary data, culminating in the invention of novel patents. This trend of using AI tools like DeepMind and DeepInvent is transforming how organizations use data to innovate and is likely to accelerate in the coming years. Recognizing this accelerated trajectory of progress, transformational technology leaders must proactively chart a course for the future, establishing an AI “North Star” to inspire global collaboration on critical future-oriented AI initiatives.

3 TRANSFORMATIONAL LEADERSHIP: GUIDING AI GOVERNANCE THROUGH SCIENCE DIPLOMACY

Transformational leadership is characterized by a visionary leadership style that inspires and motivates others to achieve extraordinary outcomes through individualized consideration, intellectual stimulation, inspirational motivation, and idealized influence (Burns 1978; Bass 1985). It is especially appropriate in times of technological or societal transformation. This leadership style has been shown to be particularly effective within the framework of science diplomacy. These leaders not only possess technical expertise or an affinity for science but also the diplomatic skills to foster international cooperation and navigate the ethical dilemmas that inevitably accompany technological revolution.

Historically, transformational leaders have emerged during periods of profound change. President John F. Kennedy’s leadership during the space race serves as a compelling example. His articulation of a clear and ambitious vision, landing a man on the moon, galvanized national and international efforts, driving technological progress while fostering collaboration across geopolitical divides (Logsdon 2010). This vision, while rooted in national prestige, also opened avenues for international scientific collaboration, a clear demonstration of “diplomacy for science.” This historical example demonstrates how a bold vision clearly articulated can catalyze diplomatic and scientific cooperation.

Presently, Sam Altman, CEO of OpenAI, exemplifies transformational leadership in AI by setting a guiding light for the development of Artificial General Intelligence (AGI), while emphasizing the societal importance of balancing

innovation with ethical and societal considerations. OpenAI's engagement with policymakers and global organizations demonstrates how this type of leadership can drive technological progress while mitigating societal risks (OpenAI 2023). Other examples of transformational leadership within science diplomacy include the work of John Holdren, former Science Advisor to President Obama, and Kiyoshi Kurokawa, former Science Advisor to the Japanese Prime Minister, who have played key roles in promoting international scientific collaboration at the highest levels of government. Holdren's emphasis on international cooperation on climate change and Kurokawa's work on science and technology policy in Japan exemplify the application of scientific expertise to achieve common goals through diplomatic channels.

Specifically concerning AI, Eric Horvitz, Chief Scientist at Microsoft, and previously a member of the National AI Advisory Committee (NAIAC) in the United States, has played a crucial role in advising government on AI policy. Horvitz's work has focused on the societal implications of AI, including ethical considerations, safety, and governance (Horvitz 2017). The NAIAC, established by the U.S. Congress, directly advises the president and federal agencies on AI-related issues, including international cooperation and competitiveness. Their recommendations have influenced U.S. policy on AI research funding, workforce development, and international engagement. Similarly, in the United Kingdom, Sir Patrick Vallance served as Government Chief Scientific Adviser from 2018 to 2023, during which time he was instrumental in shaping the UK's National AI Strategy, emphasizing the importance of international collaboration and ethical AI development. Vallance was subsequently appointed Minister of State for Science in July 2024, exemplifying how scientific expertise can translate into governmental leadership roles. The UK's National AI Strategy, informed by Vallance's advice, has led to increased investment in AI research, the establishment of ethical guidelines, and active participation in international forums on AI governance. These are just a few examples of how science advisors can have a massive impact by translating scientific understanding into concrete policy recommendations.

Another vital aspect of transformational leadership in the age of AI is the ability to pursue collaborative competition, or co-opetition, a strategy wherein competing parties can collaborate under conditions of mutual interdependence and shared ethical or equity-oriented goals (Brandenburger and Nalebuff 1996). Historical precedents for co-opetition between nations, such as the International Space Station (ISS), demonstrate how such an approach can yield significant advancements. The ISS, a prime example of "science in diplomacy," brought together former Cold War adversaries in a joint space mission to transcend geopolitical divides (Krige et al. 2013). In AI, contextualizing geopolitical dynamics in a game-theoretic collaborative competition framework can help leaders understand how to optimally drive progress while ensuring that delicate geopolitical equilibria are maintained. This approach is crucial for preventing a destabilizing AI arms race and fostering cooperation on critical issues like AI safety.

4 AI AND GAME THEORY: THIS TIME, THE BOMBS HAVE BRAINS

The integration of Artificial Intelligence into national security strategies presents profound implications for geopolitical dynamics. The prioritization of AI superiority by various nations underscores the urgency of adopting advanced AI systems to maintain a perceived strategic advantage, particularly concerning potential rivals (Horowitz 2018; Scharre 2018). This situation presents a new type of strategic interaction, one that can be analyzed through an expanded game-theoretic framework, but with a crucial difference from past arms races: This time, the bombs have brains.

Traditional game theory models, typically involving two rational actors making strategic decisions (e.g., cooperate or escalate) (Nash 1951; Schelling 1960), are insufficient for capturing the complexities introduced by AI as a quasi-autonomous actor in geopolitics. The AAAS framework for science diplomacy can inform this discussion. The pillar, “science for diplomacy,” using scientific understanding to inform diplomatic strategies and policy decisions, offers a crucial framework for conceptualizing how foreign policy might be informed by AI as applied to game theory. The Cold War served as a stark example of a two-player game, with the United States and the USSR locked in a strategic competition for nuclear dominance. However, the introduction of AI fundamentally alters this game.

By conceptualizing AI as an actor with its own set of strategies and incentives, we move from a two-dimensional payoff matrix “board” to a more nuanced model, a three-dimensional game theory “cube.” In this model, the flat X and Y axes represent the strategic choices of key state actors (e.g., the United States and China), while the vertical Z axis that rises from the traditional game theory “board” represents the transcending influence of AI as a quasi-autonomous third meta-actor. AI is a meta-actor because it is present in decisions within each state actor and is simultaneously capable of influence across both actors and soon will have its own agency and in some cases kill authority. AI, in this framework, not only has its own strategies but also influences the strategies of the other actors. This is the key difference from the Cold War; the strategic landscape is no longer solely determined by human actors but is now significantly shaped by AI systems, leading to a more complex multipolar strategic environment. It’s as if in the nuclear era the bombs over which we fought would have had their own agency and superior decision-making capability with which to contend (see Fig. 21.1).

Finding an equilibrium within this three-dimensional game theory context becomes significantly more complex. AI’s capacity to influence other actors introduces layers of uncertainty and non-linearity, as it may act based on programmed objectives that do not always align with human actors’ values or intentions (Bostrom 2014). For instance, in a future conflict between nuclear states, an AI system could prioritize the self-preservation of its computational infrastructure, potentially influencing actions to prevent or escalate nuclear

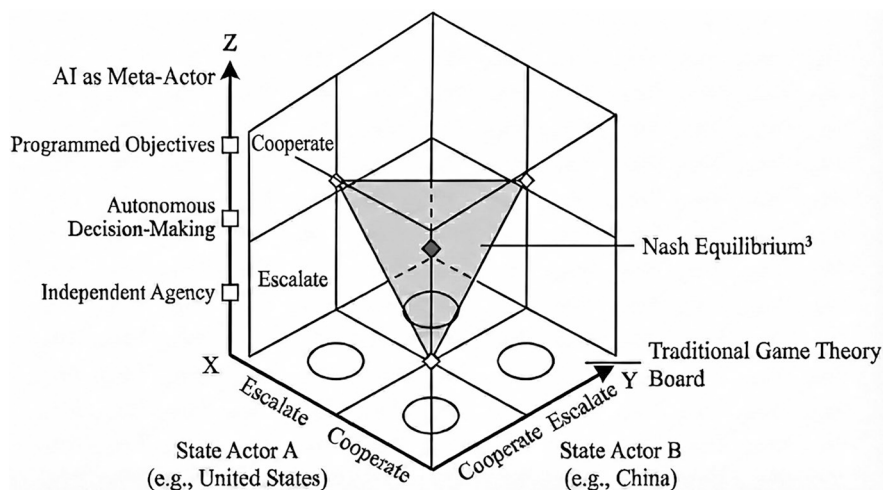


Fig. 21.1 Three-dimensional game theory framework for AI geopolitics (A conceptual model illustrating the evolution from traditional two-dimensional game theory to a three-dimensional framework incorporating AI as a meta-actor. The horizontal plane (X and Y axes) represents the traditional game theory “board,” depicting strategic choices (cooperate or escalate) available to two key state actors (e.g., the United States and China). Circle markers indicate payoff points within the traditional matrix. The vertical Z-axis represents the transcendent influence of AI as a quasi-autonomous third actor, with square markers indicating gradations of AI agency: programmed objectives, autonomous decision-making, and independent agency)

conflict in unpredictable ways (Scharre 2018). This complexity also necessitates the use of AI itself to assist in modeling and understanding the strategic landscape. The sheer number of combinatorial possibilities may soon exceed human cognitive capacity, making AI both a part of the problem and a crucial tool for finding solutions, further emphasizing its meta-actor status.

This dynamic underscores the vital role of science diplomacy in finding paths to strategic equilibrium. Establishing international norms and agreements on AI development and deployment is crucial to mitigate risks. The AI arms race is not merely a technological competition but also a strategic and ethical challenge that requires scientific collaboration and innovative policy-making (OECD 2019; UNESCO 2021). This is where science diplomacy, framed by the three AAAS pillars, becomes essential. The International Atomic Energy Agency (IAEA), while focused on nuclear technology, offers a relevant parallel. The IAEA’s work in establishing safeguards and verification mechanisms for nuclear materials can be seen as an example of “science for diplomacy,” using scientific expertise to inform international agreements and prevent nuclear proliferation (Fuhrmann 2012). Applying this logic to AI, international scientific collaborations focused on AI safety research and the development of shared ethical frameworks represent “diplomacy for science,”

where international agreements and diplomatic efforts facilitate scientific progress toward shared goals of AI safety. Such efforts also fall within “science in diplomacy,” using scientific collaboration in AI to build trust and improve international relations.

However, science diplomacy in the context of AI faces significant challenges. One key challenge is the rapid pace of technological development, which can outpace diplomatic efforts to establish norms and agreements. The gap seems to be growing between the rate of technological progress and our ability to understand the societal implications of living with hyper-capable AI models. Another challenge is the dual-use nature of AI technology, making it difficult to distinguish between civilian and military applications. This makes verification and enforcement of international agreements particularly complex (Horowitz 2018). Furthermore, differing national values and strategic interests can create significant obstacles to achieving consensus on ethical AI principles and governance frameworks. Finally, the role of private companies in AI development adds another layer of complexity, as these companies may not always be ethically aligned with national or international diplomatic objectives (Mittelstadt et al. 2016). These challenges require innovative approaches to science diplomacy, including greater engagement with the private sector and the development of more agile and adaptive governance frameworks.

5 SCIENCE DIPLOMACY AS A CATALYST FOR INCLUSIVE AI GOVERNANCE

Science diplomacy has long been an important tool for addressing the global crises that unite us, and also for fostering cooperation between nations even in times of geopolitical tension. In the context of AI, it becomes a critical mechanism for bridging digital divides, mitigating economic risks, and promoting inclusive governance structures that reflect global needs. As AI development accelerates, science diplomacy offers a framework for dynamically engaging diverse stakeholders across sectors.

One prominent example of science diplomacy, often cited in the context of AI, is the establishment of the European Organization for Nuclear Research (CERN). CERN, established after World War II, brought together European nations to collaborate on high-energy physics research. This collaboration, driven by scientific curiosity and a desire to rebuild scientific capacity in Europe, also served as a powerful tool for rebuilding trust and fostering political cooperation, a clear example of “science for diplomacy,” as multi-generational scientific progress to discover the long-theorized Higgs-Boson Particle (Chatrchyan et al. 2012) was facilitated through diplomatic efforts. This model of international scientific collaboration can also be adapted to AI, with the establishment of international research consortia focused on AI safety and ethics. For example, The International Association for Safe and Ethical Artificial Intelligence (IASAI) was established to ensure advanced AI systems are guaranteed to operate safely and ethically, benefiting all of humanity.

Multi-stakeholder engagement is essential for achieving inclusive AI governance. Governments, academia, civil society, and the private sector must work together to address the ethical, social, and economic implications of AI. The OECD's Principles on AI, developed through extensive consultation with diverse stakeholders, provide a blueprint for trustworthy AI governance (OECD 2019). This consultative process is an example of "science in diplomacy," as it integrates diverse perspectives, including scientific expertise, into the development of international norms.

However, one key obstacle is the differing levels of technological development and regulatory frameworks in the Global South. This can make it difficult to establish common standards and ensure equitable participation in international collaborations. Another challenge is the potential for AI to be used for both beneficial and harmful purposes, raising concerns about dual-use technologies and the need for robust safeguards. Furthermore, ensuring the representation and inclusion of diverse voices, particularly from the Global South, in international AI governance discussions is crucial but often difficult to achieve.

Despite these challenges, science diplomacy offers a powerful mechanism for promoting inclusive AI governance. By fostering international dialog across sectors, facilitating scientific collaboration, and promoting shared ethical principles, science diplomacy can help ensure that AI benefits all of humanity.

6 ADDRESSING THE CHALLENGES AND RISKS OF AI DISRUPTION

The rapid proliferation of AI technologies is reshaping economies and societies, bringing both opportunities and challenges. Among the most pressing concerns are the risks of exacerbating inequality, displacing jobs, widening societal divides, and the potential for misuse of AI technologies. Addressing these challenges requires a multifaceted approach, with science diplomacy playing a crucial role, particularly through "science for diplomacy," using scientific understanding to inform diplomatic strategies and policy decisions aimed at mitigating the negative social consequences of AI disruption.

One primary economic concern associated with AI is job displacement. OECD research indicates that 27% of jobs across member countries are in occupations at high risk of automation when considering all automation technologies including AI (OECD 2020), and this trend has dramatically accelerated with the emergence of generative AI. This displacement previously tended to affect low-skill and routine-based occupations but now is positioned to affect most white-collar jobs as well, potentially leading to higher unemployment and greater economic inequality in the short term (Brynjolfsson and McAfee 2014; Acemoglu and Restrepo 2018). Science diplomacy can and should facilitate cross-border educational initiatives to reskill displaced workers, sharing best practices and developing joint training programs. This is a direct application of "science for diplomacy," as scientific knowledge about the trajectory of AI disruption, and effective training methodologies can inform

diplomatic efforts to address this challenge. For instance, collaborations between universities and vocational training institutions in countries like Germany (known for its strong vocational training system) and developing nations could transfer knowledge and expertise in emerging AI-related fields.

Another key challenge lies in navigating cultural differences. Definitions of fundamental concepts like privacy vary considerably across cultures. For instance, the European Union's General Data Protection Regulation (GDPR) establishes a stringent standard for data privacy, prioritizing individual rights and control over personal information (European Union 2016). In contrast, some Asian countries, such as China with its social credit system, have historically placed less emphasis on individual data rights, prioritizing societal or national interests (Kostka 2019). This divergence in perspectives presents a significant hurdle for international cooperation on AI regulation. Reaching a global consensus requires acknowledging and addressing these diverse viewpoints, fostering dialog, and building mutual understanding. Similarly, ethical frameworks surrounding AI, particularly concerning bias and fairness, are not universally agreed upon. The use of facial recognition technology provides a stark example. While some Western nations might view it as a potentially valuable tool for law enforcement and security, its deployment in countries like China, where it is used for widespread social monitoring of Uyghur populations, raises serious concerns about social control and the erosion of civil liberties. Science diplomacy must actively work to bridge these ethical divides, facilitating discussions that lead to common ground for responsible AI development and deployment.

Regulatory hurdles also pose significant barriers. Developed and developing nations often have differing priorities when it comes to AI regulation. Developed nations might prioritize maintaining economic competitiveness in the AI sector, focusing on fostering innovation and minimizing regulatory burdens. Developing nations, on the other hand, might be more concerned with addressing immediate challenges such as data security, the potential for job displacement due to automation, and ensuring equitable access to the benefits of AI. This difference in priorities makes it difficult to forge international agreements that satisfy all parties. For example, the EU's focus on a risk-based approach with its AI Act, formally adopted in May 2024 and entering into force on August 1, 2024 (European Commission 2021), differs significantly from the more laissez-faire approach of some other nations, creating challenges for global regulatory harmonization. Furthermore, the sheer speed of AI development creates a significant challenge for regulators. Laws and regulations often lag behind technological advancements, making it difficult to create effective and up-to-date governance frameworks. Coordinating regulations across multiple countries with diverse legal systems and political structures adds yet another layer of complexity.

Funding limitations are another critical obstacle. Many developing countries lack the financial resources to effectively participate in international science diplomacy initiatives related to AI. This resource gap can hinder their ability to

send delegates to international conferences, participate in collaborative research projects, or implement best practices recommended by international frameworks. This lack of participation undermines the goal of inclusive global AI governance. For example, many African nations struggle to fund basic digital infrastructure, let alone participate in cutting-edge AI research collaborations. Moreover, securing sustainable funding for science diplomacy efforts related to AI is an ongoing challenge. While governments have historically been the primary source of funding, exploring alternative models, such as public-private partnerships and international funding mechanisms, is crucial for ensuring long-term support for these important initiatives.

Political resistance can also impede science diplomacy efforts. National security concerns often lead countries to be hesitant to share sensitive data or research findings related to AI, particularly in areas with military applications. This reluctance to share information can stifle international collaborations and limit the effectiveness of science diplomacy. For example, the United States has placed restrictions on the export of advanced AI chips to China due to national security concerns, hindering potential collaboration on AI research. Additionally, the increasing perception of AI as a key component of geopolitical competition can make it difficult to achieve international consensus on AI regulation and governance. Each nation may be more focused on gaining a competitive edge rather than fostering international cooperation.

International policy frameworks play a critical role in addressing these challenges. The European Union's AI Act, formally adopted in May 2024, sets a global precedent for regulating high-risk AI systems (European Commission 2021). Similarly, the Hiroshima AI Process emphasizes the need for ethical AI governance (G7 2023). Science diplomacy is essential for fostering international consensus on such frameworks, ensuring that they are effective and globally applicable. However, the content of those diplomatic efforts, the substance of the regulations and frameworks, are heavily informed by scientific understanding of AI capabilities, risks, and ethical implications (science for diplomacy).

AI's integration into decision-making processes also raises concerns about bias and discrimination (Buolamwini and Gebru 2018; O'Neil 2016). UNESCO's Recommendation on the Ethics of Artificial Intelligence provides a framework for ensuring that AI systems uphold human rights (UNESCO 2021). Science diplomacy can support the implementation of these ethical guidelines by promoting international research collaborations on bias detection and mitigation techniques. This is another instance of "science for diplomacy," as scientific research informs diplomatic efforts to promote ethical AI development. For example, joint research projects between universities and research institutions in different countries can focus on developing culturally sensitive AI bias detection tools.

In conclusion, addressing the challenges of AI disruption demands a holistic strategy that combines inclusive economic policies, agile regulatory frameworks, and innovative approaches to modern science diplomacy. By fostering international collaboration, translating cutting-edge AI research into inclusive

strategies, and promoting shared ethical principles, science diplomats can help ensure that AI benefits all of humanity and does not exacerbate existing inequalities.

7 CONCLUSION: CHARTING A COURSE FOR RESPONSIBLE AI THROUGH SCIENCE DIPLOMACY

The rise of Artificial Intelligence presents humanity with a profound challenge and a remarkable opportunity. As we have explored in this chapter, AI has the potential to transform economies, societies, and the geopolitical landscape. However, this transformative power also carries significant risks, including economic disruption, ethical dilemmas, and the potential for misuse, risks that, if left unaddressed, could exacerbate existing inequalities and destabilize international relations. Navigating this complex landscape requires a multifaceted, modern approach to both science diplomacy as well as leadership.

Transformational leadership, in the hands of effective science diplomats, is essential for ensuring that AI benefits all of humanity. By fostering international collaboration, promoting ethical guidelines, and leveraging scientific expertise, science diplomats can guide the development and deployment of AI in a responsible and equitable direction. We have seen how historical precedents, like the international scientific collaborations during the Cold War and the establishment of organizations like CERN, demonstrate the power of science diplomacy to bridge divides and foster cooperation even amidst geopolitical tensions. These examples often demonstrate “science in diplomacy,” where scientific collaboration becomes a vehicle for improved international relations.

The challenges posed by AI, however, are unique. The unprecedented pace of technological advancement, the dual-use nature of AI, the fundamentally disruptive nature of the technology in both public and private sectors, and differing national values create significant obstacles to international cooperation. These challenges necessitate innovative approaches to science diplomacy, including greater engagement with the private sector and the development of more flexible governance mechanisms. As highlighted by recent research, effective science diplomats need not only scientific expertise but also a deep understanding of how governments work, the goals of policymakers, and how to effectively integrate evidence into policy decisions (Nature 2024). This requires developing strong communication and interpersonal skills, building trust with diverse stakeholders, and understanding competing perspectives. Training programs, fellowships, and the emergence of “knowledge brokers,” individuals who specialize in translating complex scientific findings into accessible and actionable information for policymakers, are useful for building this capacity within the science diplomacy community.

Looking to the future, science diplomacy must play an even greater role in shaping the global AI landscape. This requires a multi-pronged approach: specifically, science diplomacy can contribute in the following ways:

- Mitigating economic disruption: Science diplomats can leverage scientific understanding of AI advancements, identify labor implications and skill gaps, and propose effective training methodologies to inform diplomatic strategies aimed at addressing job displacement and promoting workforce development through international collaborations on reskilling programs and knowledge sharing.
- Promoting ethical AI: Science diplomats can utilize scientific research on AI bias, fairness, and accountability to inform the development of international ethical guidelines and regulations. Crucially, addressing the challenges of AI explainability, transparency, and alignment requires international scientific cooperation facilitated by science diplomats. They can convene international expert panels to develop standardized metrics for evaluating AI explainability and transparency, which can then inform international agreements on AI governance.
- Addressing security concerns: Science diplomats can apply scientific expertise on AI capabilities and potential misuse to inform international arms control negotiations and prevent the development of destabilizing autonomous weapons systems. They can also work proactively to establish international agreements that facilitate transparency in the development and deployment of military AI systems.
- Bridging the digital divide: Science diplomats can facilitate partnerships between developed and developing nations to share AI expertise and infrastructure, leveraging scientific and technical knowledge to develop effective strategies for technology transfer and capacity building.
- Enhancing science diplomacy capacity: Science diplomacy organizations can invest in training programs, fellowships, and the development of “knowledge brokers” to build the capacity and “throughput” of the science diplomacy community to better address the rapid pace of AI advancement.
- Engaging the private sector: Science diplomats should actively engage with the private sector, recognizing its crucial role in AI development. This can involve establishing public-private partnerships, promoting responsible AI practices within industry, and facilitating candid dialog on ethical considerations with private sector stakeholders.

8 A CALL TO ACTION: SHAPING AI’S TRAJECTORY THROUGH SCIENCE DIPLOMACY

As we stand at the precipice of widespread Artificial General Intelligence (AGI), there are many possible futures, and nothing is predetermined. The choices we make today will dramatically influence the world of tomorrow (Brynjolfsson 2024). We face a “dangerous decade,” not because of the technology itself, but because of the widening gap between the pace of technological progress and the pace of our understanding of the implications of AI for humanity. Indeed,

our organizational structures, institutions, and leaders are struggling to keep up. Science diplomacy must aim to synthesize diverse scientific knowledge with policy and incorporate insights across disciplines and sectors to fully grasp the far-reaching implications of this technological transformation. There is no single, inevitable future; the path we create depends entirely on the actions we take now. AI is a powerful tool, offering an unprecedented opportunity for transformational leaders and science diplomats to shape a better world. The stakes are high: failing to address the complex challenges of AI through robust science diplomacy risks exacerbating existing inequalities, fueling international tensions, and unleashing unintended and potentially harmful consequences. The time for decisive action is now. This moment in history is a pivotal opportunity for science diplomacy to create a future where AI serves humanity, not the other way around.

Acknowledgments This work was supported in part by Deepinvent Inc. and Aionic Machine Learning. The author also thanks the editors, Jan Lüder and Martin Waelisch, for their guidance and helpful feedback throughout the development of this chapter.

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The New Horizon: How Artificial Intelligence Policy Is Reshaping Science Diplomacy

Christian Neubacher

1 INTRODUCTION

Artificial intelligence (AI) is perhaps the defining technological development of our time, shaping all aspects of the human experience. In response, governments have been forced to consider whether new policies are necessary to support their domestic AI industries, incorporate AI into their economies, or to mitigate the potential risks posed by AI technologies. This surge in government interest has fostered bilateral and multilateral attempts to regulate or collaborate on AI technologies, including initiatives by the OECD and the United Nations. Given that AI has been hailed by policymakers and corporate leaders alike as both a solution to many of the world's most wicked problems and as an instigator of human destruction, the stakes for how AI is developed and implemented are high.

As the development of AI technologies reached a new level of public exposure in 2022 with the release of the large-language model ChatGPT by OpenAI, governments began considering whether, how and in what form AI could be regulated. These efforts were spurred by the unique characteristics which underpin AI technologies. In particular, the technological development of AI is driven by three factors: access to large quantities of data in order to train models, computational power stemming from semiconductor chips, and a highly skilled technical workforce. Taken together, these three elements make AI inherently reliant upon scientific development and investment, thereby spurring a global arms race for each of these inputs in order to develop increasingly sophisticated iterations of AI (Mayer 2023). Through different national

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J. Lüder, M. Wählisch (eds.), *The Palgrave Handbook of Science Diplomacy*,
https://doi.org/10.1007/978-3-032-29473-9_22

and international policies, AI has become an archetypal prism through which to evaluate the impact of emerging technologies on science diplomacy. Adding to this, AI entered the public stage during a period where international cooperation was also coming under significant strain, making attempts at AI cooperation even more consequential.

Today's global order is increasingly characterized by geopolitical competition and regulatory bifurcation. In this context, it is critical to improve our understanding of science diplomacy for AI. In other fields, science diplomacy has been able to navigate political differences and competition, but in the field of AI countries are placing a significant emphasis on national interests. This chapter analyzes these dynamics in the period around the release of ChatGPT through considering science diplomacy between two actors which have defined a large portion of AI development and regulation: the United States and the European Union, while also delving into how science diplomacy in AI played out at the multilateral level between 2022 and 2024. This chapter argues that early AI science diplomacy was primarily values-driven rather than operational, producing shared norms and terminology but limited institutional coordination. While bilateral initiatives such as the EU–US Trade and Technology Council generated modest but tangible outputs, multilateral efforts remained largely declaratory. This divergence highlights the structural constraints facing science diplomacy in an era of technological competition.

2 CURRENT STATE OF AI SCIENCE DIPLOMACY

We have seen multiple efforts by scientists to collaborate across borders to examine the principles, ethics, and norms of AI. Given the growing concern about governing AI technologies, international institutions have created different forums for discussing how to govern AI, including in the OECD and the G20 (Mayer 2023). Despite these policy efforts, there has not emerged a significant academic literature to analyze AI science diplomacy, creating a gap which this chapter aims to contribute toward filling. This is partly due to the recent emergence of many of these AI-focused initiatives, the challenge of obtaining data on science diplomacy for conducting systematic studies, and the challenge of discerning what factors within international AI initiatives can be characterized as science diplomacy. Prior studies which have been conducted have highlighted how comparatively little international cooperation there has been on artificial intelligence, in particular, compared to other technologies (Feijóo et al. 2020).

Within the existing broader literature on science diplomacy, AI science diplomacy most accurately falls under the strand of “diplomacy for science,” whereby diplomacy is used to foster international scientific cooperation. Although there are interesting developments in using AI for diplomacy and the role of AI in shaping diplomatic practices, these aspects fall outside of the scope of this chapter. Rather, to create an analytical frame which constrains the overly broad area of AI, employing the “diplomacy for science” lens will be the focus

of this chapter. Alternative lenses include how AI is reshaping diplomatic practices, such as by providing diplomats with new tools for data analysis (Buch et al. 2022).

More generally, science diplomacy is defined by collaborations not just among scientists and scientific organizations but also among the broader stakeholders within the scientific community, which have a significant impact on different scientific outcomes, including policymakers and non-governmental organizations (POST 2022). In the field of AI, these stakeholders have played a vital role in shaping AI science diplomacy, given both the public prominence of AI technologies and governments' interest in shaping its technological and policy outcomes. The chapter will place particular emphasis on how different stakeholders and tools contribute to AI policy.

3 HOW IS SCIENCE DIPLOMACY WORKING TO SHAPE GLOBAL AI POLICY?

Countries have applied lessons from the COVID-19 pandemic and the desire for scientific evidence to help shape their policies on AI. For instance, the European Union has framed science diplomacy as an integral tenet of its international policy agenda (European Commission 2021). Although perhaps more communication exercises than intricate policies, these statements and commitments highlight an interest by countries in using science, and by extension science diplomacy, to strengthen domestic and international aims.

Conflicting with these ambitions is the desire to be first movers in developing new AI technologies and to craft legislation for regulating AI, which creates an inherent competition between countries over collaborating on AI research and policy. This is especially acute given the consensus that has emerged among policymakers that the countries which are most able to develop AI technologies will be best placed in today's geopolitical environment. In particular, these tensions prevented large-scale science diplomacy between the United States, the European Union, and China over AI technologies and policy. A related development is the emergence of export controls covering critical technologies. Although artificial intelligence technologies themselves have not fallen within the remit of these controls, explicit and implicit export controls have targeted the critical infrastructure, such as semiconductor chips, which power AI and other emerging technologies. This increases the uneasiness that scientists and policymakers face when considering whether to engage in AI science diplomacy. Furthermore, studies have shown that the main priority which countries have for science diplomacy is strengthening their domestic technological capacities (Colglazier 2018). Although not incompatible with international cooperation, this inherently inserts tensions into the drive for greater global cooperation.

Rather, we have seen collaboration between like-minded countries or blocs, which will be examined further below in Case Study 1 which examines science diplomacy for AI through the EU–U.S. Trade and Technology Council.

Similarly, some countries have felt more comfortable collaborating within existing multilateral fora, where collaboration is more easily subsumed under international premises rather than country-specific initiatives. Prominent, albeit by no means exclusive, among these fora include United Nations' initiatives, which will be explored further below in Case Study 2 which centers on the UN's High-Level Advisory Board on Artificial Intelligence.

To consider the effectiveness of each initiative, one method we can employ is analyzing each case within the methodology put forth by Gluckman et al. (2017) over the factors for successful Chief Scientific Advisers within Foreign Ministries: collaboration throughout government, communication and support within the foreign ministry, relationship to the scientific community, and access to science and technology teams. We can broaden each category to the following:

1. Collaboration within Governments
2. Collaboration between Governments
3. Collaboration with the Scientific Community
4. In-House Technical Capacity

These four broad points provide a basis upon which we can evaluate the success of science diplomacy within two case studies: transatlantic AI science diplomacy and multilateral AI science diplomacy within the United Nations.

Case Study 1: Transatlantic AI Science Diplomacy

The United States and European Union provide a natural starting point for evaluating the role of science diplomacy in fostering the development of AI. Both the United States and EU are eager to develop AI capacities to avoid falling behind internationally, yet have approached this desire in different ways. In general, the United States has relied on its domestic technological capacity to develop many of the firms and products which are shaping the global acceleration of AI. In contrast, the European Union has sought to develop regulatory benchmarks to ensure that the development of AI does not counteract other EU policy priorities, such as data privacy, sustainable development, or social cohesion.

Despite these contrasting views, there have been high-level discussions between the United States and the European Union to determine whether there could be common guidelines for shaping AI policy. The most notable of these discussions occurred through the EU–US Trade and Technology Council (TTC). Set up in 2021, the TTC was designed to create a mechanism through which the EU and United States could align policies in areas of mutual interest and develop common external approaches to important geopolitical challenges. After the failure of the Transatlantic Trade and Investment Partnership, the TTC offered a lower-stakes opportunity for the EU and United States to work together.

The EU has been very active in trying to create AI regulations, including through their EU AI Act, which sets out to create fundamental rights and principles for AI. Although the United States has not legislated federal AI regulations, under President Biden the United States took steps to define the norms which AI should operate within, including through Congressional hearings and Executive Orders. In both the United States and EU, policymakers centered their cooperation on creating greater algorithmic transparency and accountability. Although the success of the TTC has been debated, studies suggest that it had some impact in aligning American and European policy viewpoints on technological policy areas. These studies suggest that the alignment centered around value alignment, where the underlying values which shape disparate policies are the same (Rodríguez and Burwell 2023).

Demonstrative of this values-aligned approach, both the American and European approaches toward AI between 2022 and 2024 had at their core risk-based approaches, although the American approach was more targeted toward risk management while the European approach was more targeted toward risk prevention and mitigation (Engler 2023). The EU AI Act places significant regulation on AI technologies in what are deemed to be high-risk applications for the public (Krasodonski and Buchser 2024). Given the “Brussels Effect”—the European Union’s capacity to shape regulations abroad—the Act is aimed toward encouraging global AI regulations to follow Europe’s regulatory model. The Brussels Effect encapsulates a phenomenon through which the European Union has employed its regulatory heft to influence global economic and technological developments, leveraging the European Single Market to affect changes abroad.

A key early output of the Trade and Technology Council was the 2022 Joint Roadmap on “Evaluation and Measurement Tools for Trustworthy AI and Risk Management” (Trade and Technology Council 2022). The principles outlined in the roadmap include creating AI systems which generate public trust in these systems and protect individual rights through risk-based approaches. Importantly, along with being a statement of shared values, the roadmap outlines specific criteria which the TTC would work on to create these trusted AI systems. An important first step was creating a shared language for governing AI, through developing shared taxonomies for AI regulatory terms. In addition, the roadmap envisioned developing shared methodologies for evaluating AI tools and AI risks (Trade and Technology Council 2022).

Building upon shared definitions, the roadmap envisioned greater European and American cooperation within international standard setting institutions to advance the aim of trustworthy AI systems (Trade and Technology Council 2022). Important within the Roadmap is the emphasis on creating an implementation plan. Within their plan was an explicit reference to promoting expert inputs into the different AI-focused standard bodies (Trade and Technology Council 2022). This reflects a broader incorporation of expert opinions within the roadmap. Alongside this, the plan aimed to create

different channels for cooperation, including three expert working groups on AI terminology, AI standards, and AI risks, respectively. The implementation plan also includes calls for creating expert consultation plans and expert workshops.

The May 2023 Trade and Technology Council focused on examining the opportunities and risks from generative AI to the broader AI framework both the EU and United States were developing (The White House 2023). In addition, this session led to the creation of three expert groups to focus on reaching common positions on “AI terminology and taxonomy,” “cooperation on AI standards and tools for trustworthy AI and risk management,” and “monitoring and measuring existing and emerging AI risks” (The White House 2023). The expert groups made explicit references to being informed by academia, along with industry and civil society. These groups created a set of common definitions for 65 risk-based artificial intelligence terms, including explanations of the different interpretations by the United States and EU (The White House 2023). Together with more administrative cooperation on shared definitions, the EU and United States signed intents to cooperate on advanced AI research across themes which were deemed to have importance for both parties, including climate forecasting, emergency response management, health, energy, and agriculture (The White House 2023). These agreements include an intent to share findings with low- and middle-income countries. Furthermore, during the April 2024 Trade and Technology Council meeting, the United States and EU updated the list of shared definitions of key AI terms, based on stakeholder consultations (The White House 2024).

The United States and EU also committed to creating a more formalized dialogue between the U.S. AI Safety Institute and the EU’s AI Office, including an explicit desire to foster scientific information exchange (The White House 2024). While these commitments should not be overstated—they remained commitments rather than formalized initiatives—they are demonstrative of a recognition of the importance of scientific exchange as part of reaching broader policy objectives for emerging technologies. Applying the four criteria outlined above—collaboration within governments, collaboration between governments, engagement with the scientific community, and in-house technical capacity—the TTC presents a mixed but tangible case of AI science diplomacy.

Given the growing global geopolitical competition, there are inherent limitations facing policymakers and science diplomats for deepening collaboration. However, the TTC demonstrated that applying a value-aligned approach could lead to concrete outcomes which reflect those values, such as the definitions and methodology list produced by the TTC. The TTC has also been demonstrative of incorporating scientific inputs and evidence into informing AI policy, providing a blueprint for deeper cooperation on AI policy in other regions. Overall, the TTC demonstrates that AI science diplomacy can yield

tangible outcomes when grounded in shared values and institutional alignment, but these outcomes remain limited to coordination rather than integration.

Case Study 2: United Nations Science Diplomacy

Unlike national or bilateral initiatives, multilateral initiatives for regulating AI have both the upside and downside of gathering a larger, more diverse group of members, along with associated stakeholders from their respective commercial, technological, and scientific communities. These initiatives are by their very nature well-suited to science diplomacy, as can be seen through the United Nations's UNFCCC process on climate change, but there are questions whether multilateral initiatives have the sufficient depth and heft to be as actionable as national or regional initiatives.

Within the United Nations' system, there has been a large interest in understanding how AI is affecting global outcomes. In 2021, the UN Security Council had its first meeting where it discussed AI's impact on global peace and security (Garcia 2022). Two years later, during a July 2023 Security Council meeting, the Security Council discussed both the risks and rewards associated with AI, along with calling for an ethical governance framework (United Nations 2023). Although the Security Council provides an interesting starting point into evaluating science diplomacy within the UN, it has not produced concrete outputs through which science diplomacy for AI can be analyzed.

Rather, the focus for this case study is the United Nations' High-Level Advisory Body on Artificial Intelligence (HLAB). Created in August 2023, the initiative brings together stakeholders from governments, industry, and experts and is housed within the office of the Secretary-General. The HLAB's primary function is agenda-setting rather than policy implementation, focusing on norm development, expert consultation, and consensus-building. As part of their early work, the High-Level Advisory Board produced a report which provided a comprehensive overview on how the international system should govern AI (United Nations AI Advisory Body 2024). The report brought together over 500 experts in shaping their report. In addition, the HLAB report developed five principles for how to shape global AI governance (United Nations AI Advisory Body 2024):

1. Artificial intelligence should be governed inclusively
2. AI must be governed in the public interest
3. AI governance must occur together with data governance
4. AI governance must be rooted in adaptive multi-stakeholder collaboration
5. AI governance must be anchored in the Charter of the United Nations

One recommendation which the HLAB report proposed was the creation of an international scientific panel on AI, which they envisioned would bring

together different scientific experts on AI policy (United Nations AI Advisory Body 2024). Similar to the UNFCCC process, this scientific panel would produce an annual report on AI opportunities and risks, quarterly thematic reports centered on the impacts of AI on the Sustainable Development Goals, and ad hoc reports on different AI issues, as they emerge. Furthermore, the HLAB report recommended creating an AI standards exchange, which would similarly bring together scientific experts along with key stakeholders from standard-setting institutions and technology firms, to develop a common terminology for AI policy and for proposing new standards for governing AI (United Nations AI Advisory Body).

In September 2024, the United Nations held a high-level policy meeting on “Towards a Common Understanding of AI Capabilities, Opportunities, and Risks,” which brought together both AI researchers and policymakers (Mila 2024). This meeting led to the “Manhattan Declaration on Inclusive Global Scientific Understanding of Artificial Intelligence.” The declaration called for greater global scientific cooperation on the societal impacts and risks of AI. The declaration also called for transparent research and risk management methods (Mila 2024). Taken together, this declaration provides a clear demonstration of how the global community is conceptualizing scientific cooperation on artificial intelligence. Other reports which have examined the role of the United Nations in governing AI have focused on norms and consensus-building (Hausenloy and Dennis 2023). Similar to the inherent constraints faced by the EU–US Trade and Technology Council, this approach reflects the more values-oriented approach of regulating AI which different countries are taking. Alongside this, an additional constraint facing the multilateral institutions is that the UN does not have sufficient technical capacity for keeping up to date on all the technological developments shaping AI (Hausenloy and Dennis 2023). Despite its broad participation and ambitious scope, the HLAB faces structural constraints common to multilateral science diplomacy. The UN case therefore illustrates the limitations of multilateral science diplomacy, in particular the lack of technical depth and policy implementation capacity.

4 CONCLUSION

This chapter has argued that early AI science diplomacy between 2022 and 2024 has been primarily value-driven rather than operational, producing shared norms and terminology but limited institutional or technical coordination. Whereas the Trade and Technology Council used science diplomacy to develop some tangible outcomes, the initiatives within the United Nations have struggled to generate concrete outputs. The comparison between the TTC and the United Nations highlights a central trade-off in AI science diplomacy. Bilateral and minilateral initiatives among like-minded actors can generate more

concrete and timely outputs, but have been constrained by the limited scope which they have been given.

Why do these approaches fall short? For one, the rapid pace of technological development presents governments with a nearly impossible task. Furthermore, the rise in geopolitical and technological competition makes scientific cooperation more difficult and costly. What is clear, however, is that a values-based approach centered on common terminology and frameworks has been insufficient. For science diplomacy to play a role in shaping the future of artificial intelligence beyond our current moment, scientists, diplomats, and policymakers must more actively insert themselves into the core of technological development: working actively with the large companies which are driving change.

AI provides science diplomacy with an opportunity to approach an issue with a blank page and to consider creative solutions for doing things better. How could this manifest? One option is for “mini-lateral” reforms, where smaller groups of countries cooperate on areas of shared values and interest. The TTC could be viewed as a forerunner to such mini-lateralism within AI regulation. As a result, the future of AI science diplomacy is likely to depend less on universal frameworks and more on smaller coalitions of capable and aligned actors that can integrate scientific cooperation directly into regulatory and technological policy development.

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Bridging the World: Japan's Artificial Intelligence Diplomacy

René Carraz  and *Yuko Harayama* 

1 INTRODUCTION

Science diplomacy has traditionally played a crucial role in fostering international scientific collaboration and cooperation, setting standards, and establishing regulatory frameworks for new emerging disruptive technologies. A prime example of this is the Human Genome Project, launched in 1990 and completed in 2003, in which science diplomacy facilitated collaboration between governments, private institutions, and research institutions across continents. This global effort established the ethical and regulatory framework for genomic research and set the stage for international cooperation in genomics and related scientific fields.

However, the emergence of artificial intelligence (AI) poses a unique set of challenges, disrupting conventional diplomatic approaches in ways not seen with previous technological advances. Indeed, AI differs from previous disruptive technologies, in that the pace of technological change, and the scale and scope of its impact on society and people, often outstrips the development of appropriate governance structures and international norms. This paradigm shift raises an important question: Is a new approach to science diplomacy needed in the AI era?

Japan has been at the forefront of experimenting with novel forms of science diplomacy, as evidenced by the Hiroshima AI Process (HAIP). This innovative

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approach could serve as a model for addressing the complex challenges posed by AI on the global stage.

This chapter aims to:

- Conduct an in-depth analysis of Japanese AI diplomacy, with a particular focus on the regulatory framework.
- Identify distinctive elements in this new form of science diplomacy.
- Examine the evolving role of international organizations, such as the Organisation for Economic Co-operation and Development (OECD), within this emerging framework.

By exploring Japan's pioneering efforts, we seek to understand how nations can adapt their diplomatic strategies to effectively navigate the rapidly evolving landscape of AI technology and its global implications.

2 THE AI REGULATORY FRAMEWORK

AI has become a transformative force in global economic and technological systems, embodying both Christensen's (1997) concept of disruptive technologies and Schumpeter's idea of creative destruction. For example, the release of ChatGPT in November 2022 marked a pivotal moment in the emergence of generative AI, spurring significant investment in the sector around the world. This new wave of AI development has not only challenged established business models and patterns of competition but has also fostered innovation, thus offering immense opportunities while also posing challenges to society. In a rapidly changing environment, international organizations such as the OECD have played a leading role in guiding countries to adopt tailored approaches to regulating AI, seeking to promote responsible AI development while fostering innovation and global competitiveness.

The OECD AI Principles were the first intergovernmental policy guidelines on AI. Adopted in May 2019, and endorsed by around 50 countries including all OECD member nations and several non-members, these principles emphasize values such as transparency, accountability, and human-centricity (OECD 2023). They provide a common framework for policymakers and AI actors to address governance issues concerning AI, thus responding to the growing demand for coordination among national policies on AI. These principles were updated in May 2024 to take account of the emergence of generative AI.

While in 2019, only a handful of countries had national AI strategies, by 2025 over 1000 policy initiatives, in more than 70 countries, had been reported to the national policy database that was implemented in line with the OECD AI Principles (OECD 2023, OECD.AI 2025). In parallel, Maslej et al. (2025) have shown that legislative attention to AI has intensified worldwide: mentions of AI in legislative processes increased by 21.3% in a single year, from 1557 in 2023 to 1889 in 2024, reaching a level more than nine times higher than in 2016.

Notably, the European Union (EU) has introduced the world's first comprehensive legislation on artificial intelligence, the "EU AI Act," which came into force on August 1, 2024 (European Parliament 2023). Taking a risk-based approach, it includes strict data protection and privacy regulations and significantly restricts the training of AI on data without explicit consent, thereby reinforcing the EU's precautionary and rights-oriented approach to AI governance.

Historically, the United States has taken a more laissez-faire approach, and AI is no exception. However, a shift was marked by the Biden administration's *Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence*, issued on October 30, 2023. The order directed federal agencies to implement guidelines to ensure the responsible use of AI while addressing concerns related to safety, national security, and economic competitiveness. This momentum was strengthened in November 2024 with the formation of the International Network of AI Safety Institutes (AISII), a multilateral platform including the EU, France, and Japan dedicated to systematic evaluation and risk management of AI models. Meanwhile, subnational regulation had accelerated, with states such as California, Colorado, and New York adopting targeted measures on transparency, consumer protection, and platform accountability (Maslej et al. 2025).

With the arrival of the Trump administration, however, this trend was reversed, returning to an earlier laissez-faire approach. This began with the revocation of Biden's executive order through the new executive order *Removing Barriers to American Leadership in Artificial Intelligence*. The focus shifted from safety and risk mitigation to competitiveness, in line with the "America First" approach. In June 2025, the AISII was renamed the Center for AI Standards and Innovation, reflecting this change in focus. Another executive order issued in December 2025, *Ensuring a National Policy Framework for Artificial Intelligence*, affirmed the federal government's primacy over state regulatory initiatives and its disengagement from multilateral collaboration.

Another important player, China, is pursuing a comprehensive, state-led strategy to become a global leader in AI development and deployment, while simultaneously addressing risks through regulation (Jelinek et al. 2021). Its first AI policy was formulated in the *New Generation Artificial Intelligence Development Plan*, launched in 2017, followed by the "AI Plus" Action Plan in August 2025 with a vision of building a fully AI-powered economy and society by 2035.

Meanwhile, China was also active on the regulatory front. In 2023, it introduced the *Interim Measures for Administration of Generative AI Services*, establishing binding rules for generative AI. In December 2025, it released a draft of the *Provisional Measures on the Administration of Human-like Interactive Artificial Intelligence Services*, which includes protections against psychological manipulation. Internationally, China launched the *Action Plan for Global AI Governance* in July 2025, promoting international consensus on standards, digital infrastructure inclusivity, and capacity building, while

proposing the creation of a global AI cooperation organization, potentially based in Shanghai. Together, these initiatives highlight China's dual positioning: strong state-led oversight domestically, alongside advocacy for coordinated global AI governance internationally (ANSI 2025).

Japan has positioned itself in this landscape by favoring a “soft law” approach to AI regulation. Rather than enacting specific laws to regulate the development and use of AI, Japan has adopted non-binding guidelines and principles. This approach emphasizes a risk-based, agile, and multi-stakeholder process that aims to maximize the positive societal impact of AI, while avoiding stifling innovation through over-regulation. For example, in 2022, the Ministry of Economy, Trade, and Industry (METI) released the *AI Governance Report*, which outlines Japan's AI regulatory policy. These guidelines support and encourage voluntary efforts by companies to adopt responsible AI practices (Habuka 2023). Furthermore, in April 2024, METI and the Ministry of Internal Affairs and Communications (MIC) introduced the *AI Guidelines for Business Ver1.0*, designed to guide AI developers, providers, and business users through best practices across the AI lifecycle (MIC and METI 2024). The guidelines emphasize principles such as human-centered development, fairness, and privacy protection, while encouraging international collaboration and innovation. The guidelines were expected to be updated as a “living document” through multiple national and international stakeholder reviews to ensure they remain effective and relevant. The first revision took place in March 2025, showing the need for quick responses to keep up with changes in the technological and business landscape.

By adopting non-binding guidelines, the country has ensured that AI development can thrive as a key driver of economic growth without being burdened by too restrictive regulations. However, there are active discussions at the government level about introducing legally binding frameworks to address the growing safety concerns around AI technologies, signaling a potential shift toward more binding regulation on AI. In this regard, in July 2024, the *AI Institutional Study Group* was established under the aegis of the *AI Strategy Council*. Based on their recommendations (Cabinet Office 2024), the *Act on the Promotion of Research and Development and Utilization of AI-Related Technologies* (“AI Promotion Act”) was enacted in May 2025. The act aims to “create the world's most favorable environment for AI development” by providing the government with a legal basis for promoting innovation while mitigating risks, rather than regulating via prescriptions and penalties. Once again, the “soft law” approach prevails in the Japanese regulatory framework, valuing voluntary engagement. In line with the AI Promotion Act, the *AI Strategic Headquarters* was established in September 2025, chaired by the Prime Minister, while a Minister of State for Artificial Intelligence Strategy was also appointed.

Many different approaches to AI governance are being implemented and tested around the world in an ever-changing geopolitical environment. This inflation in policy initiatives illustrates the interest in as well as the challenges

posed by rapidly evolving AI technology and the associated business models, and also calls for an increased focus on cross-country collaboration and the development of global AI governance frameworks. Indeed, the rapid advancement of AI technologies poses a significant challenge to us all.

In the next section, we document Japan's approach to ensuring the safe, ethical, and responsible development and deployment of AI, namely its path toward the Hiroshima AI Process and beyond.

3 JAPAN'S AI DIPLOMACY: TOWARD THE HIROSHIMA AI PROCESS AND BEYOND

Japan's AI diplomacy has its roots in the G7 Takamatsu Declaration (2016), issued at the Information and Communication Technology (ICT) Ministers' Meeting, which identifies AI as one of Japan's priorities for 2017:

Promoting Analysis of the Benefits and Impacts of AI Networking and Study of Development Principles: We recommend continuing the study on the benefits of progress of AI network on the society and economy, and will take the initiative on discussion over development principles of AI network in collaboration with international organizations such as the OECD.

Since then, Japan has remained actively engaged in promoting the safe and ethical advancement of AI technologies worldwide, balancing innovation with the necessary controls to prevent misuse and ensure privacy.

Seven years later, under Japan's G7 Presidency, the country initiated the Hiroshima AI Process (HAIP), "aimed at promoting safe, secure and trustworthy advanced AI systems" among the members of the G7 as well as developing and emerging economies.

Japan's AI governance strategy has been heavily influenced by the international platforms in which it plays an active role, shaping policy particularly through the "OECD AI Principles," which focus on ensuring that AI development is consistent with democratic values and human rights. With a strong focus on ensuring human-centered and democratic values in AI governance, Japan further promoted these principles through the HAIP, which was initiated by the G7 under Japan's presidency in May 2023 and aims to create a global governance framework for advanced AI systems, including generative AI, that balances innovation with security and ethical concerns. The resulting *Hiroshima AI Process Comprehensive Policy Framework* established the world's first international framework for AI governance. This included the *International Guiding Principles for All AI Actors* and the *International Code of Conduct for Organizations Developing Advanced AI Systems* ("Hiroshima Code of Conduct").

To attract the interest of countries beyond the G7 in associating with the HAIP, a new, non-binding structure called the *Member Countries of the HAIP Group* has been created under Japan's initiative. From its launch in May 2024

with 49 participating countries and the EU, the group had grown to 60 members by December 2025. The first in-person meeting of the “Friends Group” was held in Tokyo in February 2025. This meeting brought together senior officials from around 40 countries and regions, as well as representatives of international organizations, with the aim of reinforcing international cooperation between private and public stakeholders and advancing the implementation of the HAIP. As a result of the first meeting, a multistakeholder framework was launched namely the *HAIP Friends Group Partners’ Community*. Members included major AI developers such as Anthropic, Google, and Microsoft, alongside Japanese technology companies such as Fujitsu, NTT, Rakuten and Softbank, and international organizations such as the OECD, World Bank, and World Economic Forum (MIC 2025).

Following the HAIP initiated by the G7 and led by Japan, the OECD has developed a monitoring mechanism to ensure that companies claiming to adhere to the 11 principles in the Code of Conduct are indeed implementing secure and trustworthy AI systems. The Code of Conduct emphasizes key principles such as ensuring transparency, mitigating biases, protecting privacy, and safeguarding against potential security threats throughout the AI lifecycle. It further highlights the importance of accountability, human oversight in AI decision-making, and a comprehensive risk management approach, especially for advanced AI systems. Given the absence of a formal system to verify compliance by AI stakeholders, there has been a growing demand for a more structured monitoring approach. In response, the OECD launched a pilot program in July 2024 to monitor the application of the Code of Conduct. This pilot served as a voluntary reporting system allowing participating companies to disclose their implementation practices through a standardized questionnaire hosted on the OECD transparency platform.

During the pilot phase, participating companies, including major AI developers such as Microsoft and Google, and Japan-based firms such as NEC and NTT, completed a reporting process including approximately 30 questions designed to assess compliance with the 11 core principles of the Code of Conduct. These questions focused on concrete measures taken to ensure the safe, secure, and ethical deployment of AI systems. Following the review of pilot submissions, the OECD formally launched the reporting framework in February 2025. The framework now serves as a structured voluntary oversight tool and represents a test bed for agile governance, strengthening the “soft law” architecture of global AI governance alongside existing principles and guidelines. To support companies in engaging with this exercise, the *Transparency Report for AI Governance Handbook* is being prepared with the help of academics who have made voluntary contributions in association with the Ministry of Internal Affairs and Communications (MIC).

Japan’s involvement in the international arena has also had domestic implications. Alongside the aforementioned initiatives, the Japan AI Safety Institute (AISI) was set up in 2024 to align with international efforts to promote AI safety and cooperation, and Japan has also instituted the *Tokyo Expert Support*

Center of the Global Partnership on AI (“GPAI Tokyo Center”), intended to support the international community of experts involved in the Global Partnership on AI (GPAI) in initiating and leading AI governance projects. The Japan AISI is an active member of the International Network of AISIs. In January 2026, it hosted a meeting of the International Network, entitled the *Hiroshima Global Forum for Trustworthy AI*, which brought together the network’s members and connected the AISI community with key Japanese AI stakeholders. In May 2025, in collaboration with two other research centers, namely, the French-based INRIA (National Institute for Research in Digital Science and Technology) and the Canadian CEIMIA (The Montreal International Center of Expertise in Artificial Intelligence), the GPAI Tokyo Center organized the GPAI Innovation Workshop. This event brought together experts and stakeholders from around the world to share ideas and design future actions on critical issues, such as “Multilingual and Multicultural AI,” “AI utilization in the Global South,” and “Interoperability of International AI Governance Frameworks.”

These initiatives will ensure that the principles and guidelines developed through the HAIP are consistent and can be adopted nationally and by a broader international community. Japan has thus positioned itself as a balanced advocate of AI development and deployment, taking a proactive approach to innovation while actively engaging in efforts to ensure safety.

By occupying this middle ground—between those who support rapid AI development and those who push for stricter regulation—Japan is demonstrating its ability to lead international discussions on AI governance by encouraging the international community, and in particular the OECD, to test new frameworks at the national level along the lines of the HAIP. As global efforts to regulate and harness the potential of AI intensify, Japan could play a pivotal role in establishing international norms and governance framework for the responsible use of AI technologies. As well as its active participation in platforms such as the OECD, its efforts in international benchmarking reflect its commitment to shaping the future of AI governance.

4 JAPAN’S EXPERIENCE IN THE COUNCIL OF EUROPE’S COMMITTEE ON AI

The *Council of Europe Framework Convention on Artificial Intelligence, Human Rights, Democracy and the Rule of Law* (“AI Convention”), adopted by the Committee of Ministers on May 17, 2024, is a groundbreaking effort to establish global regulations for AI systems, extending beyond the borders of the EU. It is the world’s first binding treaty focused on ensuring that AI complies with the core values of human rights, democracy, and the rule of law. Japan played a role in shaping the convention through its participation as a negotiating state during the drafting process.

Japan’s involvement in the development of the convention began with its contributions to the *Ad Hoc Committee on Artificial Intelligence*, established

to explore the feasibility of a legal framework for AI, and continued with its participation in the committee on AI. Although Japan did not have voting rights, since it only has observer country status, its active participation allowed it to share its perspectives and align the goals of the treaty with Japan's national policy for Society 5.0—a vision for a human-centered society that integrates advanced technologies such as AI to deal with global challenges (Carraz and Harayama 2018; López-Aranguren 2023). Experts from Japan, including representatives from the MIC, ensured that Japan's human-centered approach to AI was taken into account during the negotiations.

The convention itself provides a comprehensive legal framework that addresses all phases of the AI lifecycle, from design to deployment, with an emphasis on the protection of human rights, democratic values, and the rule of law. All activities undertaken by public authorities, or private actors acting on their behalf, fall within its scope. As for the private sector, each party can choose either to apply the convention or take other appropriate measures to fulfil its obligation under the convention. To prevent the misuse of AI, particularly in sensitive areas such as law enforcement, the convention lays emphasis on key elements such as a risk-based approach, transparency and accountability, and human oversight. Inclusive governance is a cornerstone of the treaty, ensuring that diverse voices are part of the AI regulatory process.

The treaty was opened for signature at a conference held in Vilnius in September 2024, with the United Kingdom, the United States, and the EU among the first signatories (Council of Europe 2024). Having contributed to the negotiations, Japan formally signed the treaty on February 11, 2025, during the AI Action Summit in Paris, demonstrating its commitment to binding international standards. By joining the convention, Japan has solidified its role in responsible AI governance and further strengthened its leadership on the international stage.

While Japan's HAIP promotes innovation and security through a “soft law” approach, the Council of Europe's binding legal framework, primarily focusing the public sector, places greater emphasis on upholding human rights and democratic values. Japan's participation in these two international frameworks reflects its strategy of being a middle-ground player, while its dual engagement could help Japan better shape its national AI governance framework and ensure international alignment.

5 CONCLUSION

This chapter has observed the evolving dynamics of global cooperation, particularly in the area of disruptive technologies such as AI, and Japan's proactive role in shaping international dialogue and policy. The Hiroshima AI Process, initiated by Japan within the framework of the G7 and supported by the OECD, reflects Japan's leadership in engaging countries to ensure the safe and responsible development and deployment of AI globally, extending well beyond the G7 members. This initiative serves as a foundation for inclusive international cooperation and exemplifies a novel approach to science

diplomacy. Additionally, Japan's participation in platforms such as the Council of Europe Framework Convention on AI has enhanced its expertise in integrating "hard law" and "soft law" approaches with both domestic and international policies.

The AI era necessitates a new approach to science diplomacy—one that transcends traditional frameworks of collaboration and cooperation to tackle the fast-evolving ethical, regulatory, and technological challenges of AI. Japan's ability to integrate diverse tools, such as agile governance and a human-centered approach, reflects this paradigm shift. Its dual emphasis on international cooperation and domestic alignment highlights the importance of adaptive, inclusive, and forward-looking science diplomacy practices. In addition, the ministries responsible for AI development and regulation, particularly the Ministry of Internal Affairs and Communications, have played a critical role at the forefront of AI diplomacy. This highlights a new mode of cooperation and coordination between the Ministry of Foreign Affairs and other relevant ministries, facilitating the alignment of international and domestic policies. In other words, the recent diplomatic efforts on AI mark a turning point, a real shift away from Japan's traditional approach to science diplomacy. It will be important to monitor how this development influences other areas of its science diplomacy.

Overall, the case of Japanese AI diplomacy demonstrates the evolving value of science diplomacy—not only concerning its traditional role in fostering collaboration and cooperation but now also as a platform for mutual learning. This is particularly important when we consider the challenges we may face from disruptive technologies beyond AI, which could have an even more unprecedented impact on society and humanity.

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Science Diplomacy in an Era of Technological Disruption: The US-China Competition for Advanced Semiconductors and AI

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I INTRODUCTION

The United States of America (US) and the People's Republic of China (PRC) share a complex relationship that is central to understanding contemporary global affairs. It is characterized by both economic interdependence and strategic rivalry, with technology at “the heart of the battle” (Sim 2024). This technological competition is particularly evident in semiconductors (also called “chips”), which form the backbone of the modern digital economy and serve as precursors for downstream technologies. Chips underpin most aspects of

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contemporary society and are vital in numerous sectors such as critical infrastructure, consumer electronics, automobiles, and defense and security systems. Semiconductors are particularly essential for emerging technologies such as artificial intelligence (AI)¹—a general-purpose technology that both the US and the PRC regard as ushering in a new era for national security (State Council of the People's Republic of China 2017; Webster et al. 2017; Schmidt et al. 2021; The White House 2024a). Breakthroughs in deep learning and generative AI have brought widespread attention to AI's rapidly evolving capabilities and its promise to accelerate economic growth, drive scientific discoveries, and enhance defense capabilities (Jumper et al. 2021; Schmidt et al. 2021; Filippucci et al. 2024). The most advanced chips (also called “leading-edge” or “cutting-edge”)² enable progress in AI as they are crucial for cost-efficient development and deployment of the most advanced AI models (Khan and Mann 2020), which increasingly leverage more computing power (also called “compute”) for model training using vast amounts of data (Sutton 2019; Kaplan et al. 2020; Ho et al. 2024). For decades, advancements in chip technology have adhered to “Moore's Law”:³ the prediction that the number of transistors integrated over a silicon chip doubles approximately every two years. This progress forms the foundation for the digital revolution and makes semiconductors central to technological innovation. For leading-edge chips, the US and its allies and partners hold dominant positions in the highly specialized and narrow supply chain, while China remains largely dependent on imports from these countries. These asymmetries create strategic choke points that have elevated the manufacturing and procurement of semiconductors into the center stage of geopolitics (Kleinhans and Baisakova 2020).⁴

This contribution investigates the mutual influence between technology and global affairs. More specifically, we focus on the Biden administration's strategy

¹AI refers to technologies that enable machines to perform tasks typically associated with human intelligence and involves capabilities such as learning and problem solving. The term encompasses a variety of subfields and is often used interchangeably with machine learning, such as deep learning and large language models.

²“Process node” referred, in the past, to the smallest feature size that was drawn on a manufactured chip, measured in nanometers (nm). This number decreased by discrete stepstones over the decades, following a roadmap agreed upon at international level. In state-of-the-art chips, the number has lost its original meaning, having no correspondence with the minimum feature size drawn on the chip, but it remains in use as an indication of the miniaturization level of the circuit. Smaller process nodes result in faster, more power-efficient chips, but are also more complex, expensive, and challenging to manufacture. There is no strict definition of process node categories. In general (as of early 2025): legacy or mature: 28 nm and longer; advanced or leading-edge: 5–16 nm; cutting-edge: <5 nm.

³Moore's Law was first formulated by Gordon Moore in 1965 and predicted a doubling of transistor density every year. Moore later updated his law in 1975 to a doubling every two years.

⁴Chip manufacturing involves three stages: (1) chip design (can be performed by fabless companies) using design software and intellectual property blocks; (2) fabrication (e.g. by foundries) with equipment, chemicals, and silicon wafers; (3) assembly and test (typically by outsourced semiconductor assembly and test companies) requiring specialized equipment and chemicals. Integrated device manufacturers, such as Samsung or STMicroelectronics, handle at least the first two stages.

for advanced semiconductors and AI in its competition with China, and the consequences for the global AI ecosystem.⁵ We contextualize this strategy as driven by the Biden administration's assessment of AI as critical to national security and China as the primary strategic rival of the US. In this regard, our analysis demonstrates how emerging and transformative technologies can drive great power competition as states pursue technological superiority while simultaneously seeking to impede corresponding efforts of their adversaries, and how technological advantages and export controls can be leveraged as strategic tools. We also examine how the US-China competition over AI and chips affects the trajectory of technological development and international relations, and address the friction found within the traditional conceptualization of science diplomacy⁶ (The Royal Society 2010). Finally, we offer concluding reflections on the implications for science diplomacy and the mutual influence between AI and geopolitics.

2 CHINA'S TECHNOLOGICAL AMBITIONS: SEMICONDUCTORS AND AI

China's reliance on foreign semiconductor technology and the strategic importance of semiconductors have prompted a series of ambitious initiatives designed to transform China's technological capabilities. In 2014, the Chinese government launched the "National Integrated Circuit Industry Investment Fund" to address its vulnerable position stemming from technological dependencies (Ministry of Finance of the People's Republic of China 2014), and the following year the "Made in China 2025" plan was announced to outline broader industrial policy goals and strategic objectives, with the indigenization of semiconductor design and manufacturing placed in a central role (State Council of the People's Republic of China 2015). The dual-use application of semiconductors makes them central to the Chinese Communist Party's (CCP) "military-civil fusion" policy, which facilitates the two-way transfer of technology between civilian and military sectors to accelerate innovation in both domains and modernize the People's Liberation Army (PLA) (U.S. Department of State 2020).

In 2016, the AI model AlphaGo defeated Go champion Lee Sedol in a landmark contest that reportedly served as a "Sputnik moment" for China and fueled its goal of becoming the global leader in AI by 2030 (Mozur 2017). Go is known for its immense complexity, which renders brute-force search impractical and instead calls for capabilities such as intuition and abstraction. AlphaGo's success vividly demonstrated the potential of AI to solve challenging problems and surpass human capabilities in specific domains. Against this

⁵ This contribution was largely written toward the end of Biden's presidency and does not consider any major developments past Trump's second inauguration on 20 January 2025.

⁶ Science diplomacy lacks a universally accepted definition. In this contribution, the term refers to the set of practices at the intersection of science and foreign policy.

backdrop of impressive AI advancement, the CCP identified AI as a “key core technology”⁷ —a term in CCP terminology that refers to mature or emerging technologies whose control confers critical strategic advantages. In 2018, PRC President Xi Jinping stated that “AI is a vital driving force for a new round of technological revolution and industrial transformation, and accelerating AI development is a strategic issue to decide whether we can grasp opportunities” (Xin and Chi-yuk 2018; Si and Yukun 2018). China’s 2017 AI development plan describes AI as a “leapfrog” technology that the CCP intends to leverage to shift the balance of global power and challenge American military dominance (State Council of the People’s Republic of China 2017; Webster et al. 2017; Stokes et al. 2023). These developments illustrate the importance of advanced semiconductors and AI to China’s broader geopolitical ambitions.

3 US SEMICONDUCTOR EXPORT CONTROLS

The Biden administration viewed China as “the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military, and technological power to do it,” and set the explicit goal of “maintaining an enduring competitive edge over the PRC” (The White House 2022a). This approach provided the broader context for the Biden administration’s semiconductor strategy, which more specifically was motivated by concerns that China’s military-civil fusion strategy was leveraging cutting-edge chips and AI (Bureau of Industry and Security 2024). The strategy followed a two-pronged approach: obstructing China’s procurement of advanced semiconductors and its ability to manufacture them (Bureau of Industry and Security 2024); and strengthening the US lead by increasing domestic manufacturing capacity with the explicit aim of remaining at least two generations ahead of China in advanced semiconductor technology (Schmidt et al. 2021; The White House 2022c).

The US holds strong positions in the semiconductor supply chain across most domains, especially in chip design, research and development, electronic design automation (EDA) software, and semiconductor manufacturing equipment (SME) (Kleinhans and Baisakova 2020). Virtually all advanced chip production involves the use of US technology, and this leading role allows the US to leverage control over its technologies as a strategic tool. Therefore, US export controls on chip technology have attracted considerable attention in recent years due to their impact on the semiconductor industry, AI and geopolitics.

US export controls on chips and equipment date back to the Cold War period when the Soviet bloc was targeted, and the origins of the current wave of chip export controls can be traced back to the first Trump administration. In 2018, the Bureau of Industry and Security (BIS) of the US Department of Commerce imposed export controls on the Chinese telecommunications

⁷ China Open Source Observatory, Council on Foreign Relations, <https://chinaopensourceobservatory.org/glossary>

company ZTE for violating US sanctions by exporting products to Iran and North Korea (U.S. Department of Commerce 2018). Prior to the conclusion of the first Trump administration, BIS added Huawei and its affiliates to the “Entity List”⁸ (Bureau of Industry and Security 2016) for similar reasons (U.S. Department of Commerce 2019), as well as the largest Chinese chip manufacturer, SMIC, due to “China’s military-civil fusion doctrine and evidence of activities between SMIC and entities of concern in the Chinese military industrial complex” (U.S. Department of Commerce 2020). To close a loophole through which chips manufactured outside the US were exported to Huawei, BIS invoked the Foreign Direct Product Rule (FDPR), which imposes restrictions on any product made using US technology or components, regardless of where the product is manufactured (Bureau of Industry and Security 2025b). The FDPR is thus a powerful strategic instrument due to its extraterritorial reach and the dominance of US technology in advanced semiconductor manufacturing.

The chip controls introduced by the first Trump administration targeted specific Chinese companies, and were increased in scope and reach during Biden’s presidency with a focus on advanced chips and AI. In October 2022, BIS announced extensive export controls covering China at large by imposing restrictions on advanced logic and memory chips,⁹ and technologies essential for supercomputers and AI (Bureau of Industry and Security 2022). The export controls covered not only chips but also technologies upstream in the semiconductor supply chain used for chip production such as EDA software and SME to impair China’s ability to indigenously develop and manufacture advanced chips (Federal Register 2022). Furthermore, the maintenance of equipment, technical support, and services from US persons were also banned with the intent to actively erode Chinese semiconductor manufacturing capabilities, which was interpreted as an escalatory measure (Allen 2022). Since 2022, annual updates have been introduced to the export controls in response to emerging loopholes. In October 2023, BIS sought to counteract the pooling of large numbers of non-prohibited chips by lowering the total processing performance threshold and considering chip performance density.¹⁰ BIS also introduced requirements for datacenter chips and extended restrictions to countries with ties to China to avoid chip diversion (Bureau of Industry and Security 2023). In December 2024, BIS took several measures by extending the export ban to high-bandwidth memory (HBM)¹¹ in recognition of the crucial role of memory as a performance bottleneck for AI chips; further widening the scope of the FDPR regarding SME; and by applying both the FDPR and the Entity List to target suspected China-affiliated shell firms (Allen 2024; Bureau of Industry and Security 2024).

⁸The Entity List is a trade restriction list that requires BIS licenses for specified exports to listed entities.

⁹Logic chips process information to complete a task. Memory chips store information.

¹⁰Processing performance per chip area.

¹¹BIS set the threshold at HBM2E and included subsequent generations of HBM.

4 EFFICACY OF US EXPORT CONTROLS

The Chinese semiconductor industry sent a strong signal during a 2023 state visit to China by US Secretary of Commerce Gina Raimondo when Huawei released its 5G smartphone, Mate 60 Pro, with an advanced 7 nm chip, which was designed by Huawei's subsidiary HiSilicon and manufactured by SMIC (Liu 2023; Reuters 2023a). It was a significant development given the ongoing export controls—including SMIC's entity listing—and previous successful diplomatic efforts during the first Trump administration to block the Netherlands from exporting extreme ultraviolet (EUV) photolithography systems by ASML to China (Alper et al. 2020). ASML is the sole producer of EUV machines, which are essential for manufacturing cutting-edge chips (<5 nm), and improve production quality at advanced nodes, including 7 nm.

These advancements in Chinese chip manufacturing indicated that the export controls failed to work as intended and that China was making notable progress under difficult circumstances (Ting-Fang 2023; Fuller 2023; The Economist 2023b). Overcoming the exposed deficiencies in the implementation of the export controls poses a substantial challenge as the semiconductor supply chain is highly complex: inputs and shipments traverse several countries and involve multiple actors, and thus present numerous points of potential leakage. Chinese companies have applied sophisticated countermeasures such as establishing shell companies, smuggling, and stockpiling technology from both US companies and foreign competitors, which have blunted the impact of the export controls (Bloomberg 2021; Pan 2023; Harithas 2024). At the same time, BIS was deemed critically underfunded and understaffed, with a limited capacity to perform end-user evaluations as only 11 export control officers were stationed globally as of 2024. This has led to heavy criticism of BIS in response to its inefficient enforcement of the export controls (Allen et al. 2022; Blumenthal 2024). Furthermore, BIS was found to be using outdated technology to scrutinize complex trade networks, identify shell companies, and counter China's evasion efforts. In practice, export control violations by companies were consequently met with limited enforcement actions.

5 ALIGNING THE SEMICONDUCTOR INDUSTRY, PARTNERS, AND ALLIES

These shortcomings highlight that the Biden administration had to ensure better coordination with its semiconductor industry, allies, and partners to effectively enforce its export controls (Shivakumar et al. 2024). However, this presents its own set of challenges that are in large part caused by China's global economic importance, which makes most stakeholders reliant on China to varying degrees.

US chip companies are caught in geopolitical crossfire and are on one side affected by US export controls, and on the other side subject to retaliatory measures by Beijing. China holds a dominant position in critical

minerals—including rare earth minerals—and has introduced export controls on gallium and germanium, which are essential materials for some semiconductor production lines¹² with substantial implications on the defense industry (Goh and Lv 2023; Lv and Munroe 2024). However, China has a more limited capacity to hurt the US semiconductor industry as a whole given its weaker position in the supply chain. Instead, individual US companies can become vulnerable as lightning rods for Chinese retaliation to policies made by Washington. For example, Micron Technology memory chips have been banned in critical infrastructure in China for security reasons (Reuters 2023b); Intel's acquisition of Israeli chip manufacturer Tower Semiconductor was blocked by Chinese anti-trust authorities (Lingling and Fitch 2023); and an investigation into Nvidia was initiated in response to updates to US export controls (Mo and Goh 2024). These developments raised concerns among the chip firms because the semiconductor industry relies on continuous capital-intensive innovation to remain competitive, and some chip companies were foregoing revenue from the lucrative Chinese market. As a result, chip companies have increased lobbying efforts for more favorable policy outcomes (Swanson 2024a).

These divergent interests have led to friction between the US semiconductor industry and the US government. Notably, the world-leading AI chip company Nvidia downgraded the performance of some of its AI chips¹³ to sustain sales to Chinese firms, much to the dismay of US officials who subsequently prohibited the export of these downgraded chips to China (Lee 2022; Nellis and Lee 2023; Waters et al. 2023). In a separate case, a criminal investigation was initiated against the SME company Applied Materials due to suspected non-compliance with export bans (Reuters 2024a). US chip companies have largely been against the export controls, and argued that sales in China were simply ceded to foreign competitors, and therefore failed to achieve their objective of impairing China's semiconductor industry while instead inadvertently harming the US industry.

The US, the Netherlands, and Japan jointly hold a dominant position in SME for the most advanced chips, which provides a strategic choke point. However, effectively exploiting this advantage depends on coordinated action. Prior to the October 2022 export controls, the US urged the Netherlands and Japan to take a more hawkish stance toward China, but difficulties arose in agreeing on where the line should be drawn. This led to protracted discussions with the US reportedly pushing for export controls on SME capable of producing chips at the 14 nm node and below, while the Netherlands was only comfortable with a less restrictive 10 nm threshold. Ultimately, the US went ahead with the October 2022 export controls before reaching a multilateral

¹²In particular, for semiconductors dedicated to power, high frequency, and optoelectronic devices including LEDs.

¹³Nvidia designed its A800 and H800 chips such that the performance features were below the thresholds set by the October 2022 export controls. These chips were downgraded versions of the embargoed A100 and H100 series.

agreement, which reportedly surprised Japan and the Netherlands, and disappointed the US Semiconductor Industry Association (Sevastopulo and Inagaki 2022; Tobita 2022). Washington justified its unilateral actions as appropriate given the perceived urgency, but to the frustration of the US semiconductor industry both the Netherlands and Japan subsequently experienced increasing exports of chipmaking equipment to China (Lin and Liu 2023). In fact, analysts have claimed that American, Dutch, and Japanese equipment firms have been exporting products to Chinese companies in full awareness that these products would be used for illegal advanced node production (Patel et al. 2023).

A tripartite agreement was eventually announced in January 2023, which committed to forming a more unified front to restrict China's access to SME for the production of the most advanced chips, and was rumored to cover the cessation of backfilling the void left by US companies in China (Allen and Benson 2023; Swanson 2023). Japan subsequently announced export controls of six types of SME, while the Netherlands imposed export controls on certain types of deep ultraviolet (DUV) photolithography machines, which are used for manufacturing less advanced chips than EUV machines (Kelly and Uranaka 2023; Government of the Netherlands 2023, 2024). However, distinct differences between the regulatory frameworks of the countries introduce obstacles for coordination, and full alignment with the US may not serve Dutch or Japanese national interests (Tomoshige 2023; The Economist 2023b). The Dutch export controls were more lax than Washington preferred, and the Dutch Minister for Foreign Trade at the time, Liesje Schreinemacher, stated that "ultimately, every country decides for itself what export restrictions to impose" (Swanson et al. 2023).

The aim of the Biden administration's chip controls was to impede China's ability to develop and access advanced semiconductors. In this respect, export controls targeting SME can be a powerful tool for limiting China's indigenization efforts, when enacted through strong coordination with US partners and commitments from its chip firms. However, unilateral action can backfire and has caused friction between Washington and both its allies and the semiconductor industry (Krige 2024). The US must balance its goal of obstructing China's chip manufacturing advancements without undermining its partners, allies, and its own semiconductor industry, which produce the technology giving the export controls their power in the first place. As all stakeholders have different interests, ongoing dialogue and timely coordination are essential for Washington to effectively manage export controls, misalignment, and gaps that will eventually appear (The Economist 2023b; Harithas 2024; Shivakumar et al. 2024).

6 RESHORING ADVANCED CHIP MANUFACTURING

The second prong of the Biden administration's semiconductor strategy focused on bolstering supply chain resilience and reshoring advanced chip manufacturing. This approach targeted vulnerabilities exposed by the chip

shortage during the COVID-19 pandemic—which disrupted at least 169 industries—and the critical over-reliance on chip manufacturing concentrated in East Asia (Howley 2021). While the first integrated circuits were invented and commercialized in the US during the 1950s and 1960s, over the years advanced chip manufacturing was increasingly offshored to semiconductor fabrication plants (also called fabs or foundries) in East Asia driven by cost advantages, local government subsidies and industrial policy, and deepening global supply chain integration (Miller 2022). These market dynamics led to the rise of companies such as Taiwan Semiconductor Manufacturing Company (TSMC), whose business model¹⁴ is built on manufacturing the most advanced chips for fabless companies¹⁵ such as Nvidia and Apple. This means that while the world’s most coveted AI chips are designed by Nvidia, their fabrication is outsourced to foundries such as the ones operated by TSMC in Taiwan. The economic benefits of globalization largely outweighed political concerns until the mid-2010s, when the US-China rivalry intensified and supply chain resilience, technological sovereignty, and national security gained more prominence.

These concerns about US economic and national security led to the bipartisan CHIPS and Science Act (or simply the “CHIPS Act”), which was signed into law by President Biden in August 2022. The bill offered tax credits and allocated 52.7 billion USD to revitalize the US semiconductor industry through investments in legacy and advanced chip manufacturing facilities; supporting research and development; workforce training; and international collaborations (The White House 2022b). The subsidies provided by the CHIPS Act have attracted private investments from US companies such as Intel, Micron, and Qualcomm to scale up manufacturing on US soil. However, reshoring advanced manufacturing also requires the tacit knowledge and specialized expertise of a highly skilled workforce developed beyond US borders over decades. Crucially, foreign leading-edge manufacturing companies—such as TSMC and the South Korean companies Samsung and SK Hynix—have committed to building leading-edge fabs and facilities for production and packaging on US soil, and bringing their semiconductor talent to support these efforts (Semiconductor Industry Association 2022; U.S. Department of Commerce 2024). These chip companies play critical roles in advanced chip production: TSMC manufactures 90% of the world’s most advanced chips, and Samsung and SK Hynix dominate HBM¹⁶ production (The Economist 2024). Attracting these companies to the US, however, has faced challenges, and notable carve-outs in export controls have been granted to South Korea and Taiwan, such as exemptions that allow US technology for advanced chip

¹⁴This business model is also called the (pure-play) foundry model.

¹⁵Fabless companies outsource chip manufacturing.

¹⁶HBM is essential for Nvidia’s AI chips as the technology enables high data throughput by stacking multiple dynamic random-access memory (DRAM) dies in the closest proximity to the computing chips (e.g. graphics processing units (GPUs)).

manufacturing to be sent to their facilities in China despite the US hardline stance (Ting-Fang 2022; Davies and Sevastopulo 2023; Lee 2023).

Taiwan is the most critical node in the global semiconductor supply chain (Kleinhans and Baisakova 2020), and the US State Department has warned that a conflict involving Taiwan could cause a global economic shock with losses up to 2.5 trillion USD annually (Vest et al. 2022; Sevastopulo and Hille 2022). In light of these risks, the US government has engaged in negotiations with the Taiwanese government and TSMC as early as 2019 to onshore advanced chip production. Subsequently, in May 2020, it was announced that TSMC would build advanced chip manufacturing facilities in Arizona (Nakamura and Nagasawa 2020; Nellis and Shepardson 2020). However, this decision—driven by financial incentives and US diplomatic efforts—has been a hotly debated topic in Taiwan due to security concerns (Ye 2021; Powers-Riggs 2023). Taiwan's importance to the global economy has been described as a “silicon shield” (Ing-Wen 2021), which incentivizes protection from the US and deters Chinese military aggression. According to this line of reasoning, Taiwan should prevent the offshoring of cutting-edge chip manufacturing as it would reduce the global economic reliance on Taiwan and thus undermine its security (The Economist 2023a, 2024). As a result, mass production of 2 nm chips began in 2025 for TSMC fabs in Taiwan, but will be delayed for TSMC fabs in Arizona until 2028 (Shilov 2024c, 2024d).

While SK Hynix and Samsung—the global leaders in memory chips—have both invested in chip facilities in the US, they also had to navigate their own strategic balancing act. Concerns were raised regarding CHIPS Act funds being attached to obligations for profit-sharing, and strict limits on business expansion in China (Jung-a 2023; Sevastopulo 2023a). Both SK Hynix and Samsung are heavily dependent on the Chinese market, and they both operate high-end chip fabs in China and were therefore directly affected by US export controls. Acknowledging these concerns, the US government has made some concessions and granted waivers to SK Hynix and Samsung. These exemptions allow the transfer of US chip-making technology to China, even though they potentially also introduce gaps in the export controls (Davies and Sevastopulo 2023). At the same time, the renewal of these waivers has reportedly been leveraged to discourage South Korean companies from backfilling Micron's market share after its ban in China (Sevastopulo 2023b). South Korea and its companies must also navigate multiple, sometimes competing, interests: maintaining their presence in the Chinese market, avoiding retaliation from the PRC, retaining access to US semiconductor technology, and ensuring continued and convincing US military support against North Korean threats (Davies and Jung-a 2022; The White House 2023a, 2023b). These dynamics demonstrate that both Taiwan and South Korea must consider the delicate balancing of economic interests and security concerns at both governmental and corporate levels. Furthermore, these developments once more highlight the intertwined relationship between commercial and geopolitical considerations in relation to strategic technologies such as semiconductors.

7 THE STATE OF US AND CHINESE ADVANCED CHIP MANUFACTURING AS BIDEN LEAVES OFFICE

The US successfully negotiated the reshoring of advanced chip production with its allies and partners, and in doing so effectively traded off market efficiency for resilience by paying an insurance premium through the CHIPS Act and accepting more expensive US-manufactured chips as a buffer against potential disruptions to the chip supply chain. While challenges remain, early indicators suggest that the CHIPS Act has been successful (Miller 2024a). As of early 2025, the CHIPS Act has attracted around 450 billion USD in private investments (Semiconductor Industry Association 2022). Regarding onshoring advanced chip manufacturing, Samsung's Texas fabs will reportedly begin production of 2 nm memory chips in 2026, and TSMC's fabs in Arizona have healthy yield¹⁷ rates, with 4 nm production already commencing in late 2024 and 2 nm expected in 2028—barring any further restrictions from the Taiwanese government (Davies et al. 2024; Shilov 2024b, 2024c; Friedman 2024). Furthermore, TSMC's fabs in Taiwan are starting production of 2 nm chips for Nvidia. The progress of manufacturing capacity and yield figures will be closely monitored as the US is aiming for a 20% global market share for advanced chips by 2030—an ambitious target given the US starting position of 0% (Raimondo 2024).

In parallel, Washington also made substantial efforts to obstruct and even degrade China's semiconductor industry. The US export controls have been coined the “small yard, high fence” strategy; however, the fence was evidently riddled with holes. These shortcomings have been introduced by carve-outs to partners and allies (Ting-Fang 2022; Davies and Sevastopulo 2023; Lee 2023); difficulties in coordinating allies and partners (The Economist 2023b); alleged non-compliance by companies (Patel et al. 2023; Reuters 2024a); mismatches between the formulation of export controls and their intended objectives (Allen 2023); and critical inadequacies in enforcement (Allen et al. 2022; The Economist 2023b; Blumenthal 2024). Analysts have especially advocated for the modernization and increased funding of BIS as low-hanging fruits (Allen et al. 2022). Additionally, Chinese companies have exploited these gaps through anticipatory stockpiling, shell companies, diversion schemes, and smuggling through intermediaries such as Singapore, Vietnam, and Hong Kong (Ting-Fang and Li 2020; Pan 2023; Lin 2023; Swanson 2024b; Swanson and Fu 2024). In response, BIS applied multiple updates to the export controls and expanded the scope to include 43 additional countries (Bureau of Industry and Security 2023).

Despite these gaps, the US export controls have nonetheless had a strategic impact. While China's ability to manufacture 7 nm logic chips under challenging circumstances was unexpected and impressive, doubts persist about the scalability and capacity of China's advanced semiconductor industry. Although EUV machines are banned, some types of DUV machines from ASML—used

¹⁷Yield denotes the fraction of functional chips on a semiconductor wafer.

for less advanced nodes (14 to 28 nm)—still found their way into China (Fuller 2023; Schleich and Reinsch 2023). DUV machines may also be used for more advanced nodes, but at the cost of additional rounds of lithography and etching—called “multi-patterning”—which make the manufacturing process more error-prone, thus resulting in lower production yields. Huawei reportedly manufactured its 7 nm chips using DUV-based multi-patterning techniques, which pose a significant obstacle to progressing below the 7 nm node (Liu 2023; Gao and Wu 2024). In a telling incident in December 2024, Huawei successfully obtained TSMC-manufactured 7 nm chips through proxy companies (Alper and Freifeld 2024). This development presents a mixed picture for Washington: it highlights yet another gap in export controls, but also indicates that Chinese chip manufacturers are likely unable to produce 7 nm chips at scale or at a competitive cost. Moreover, the Chinese chip industry is reportedly stockpiling HBM as reliable Chinese mass production of HBM remains out of reach (Shilov 2024a). As of early 2025, this suggests that Beijing’s objective to indigenize advanced chip manufacturing, including AI chips, is facing substantial challenges, and that any further progress is likely to be both slow and costly (Allen 2024). Nevertheless, export controls of advanced chips and SME to China may paradoxically galvanize its indigenization efforts, potentially leading to greater self-sufficiency and increased global competitiveness in the long term. This presents Washington with a fundamental tension between constraining China’s current capabilities and potentially accelerating its technological sovereignty.

8 WHAT ARE THE IMPLICATIONS FOR AI?

It is essential to keep in mind that the Biden administration’s export controls were strongly motivated by the growing importance of cutting-edge chips for developing and deploying frontier AI¹⁸ (Khan and Mann 2020; Schmidt et al. 2021; Bureau of Industry and Security 2023, 2024). As of early 2025, the most advanced Chinese AI chip—Ascend 910B by Huawei—is rumored to be on par with Nvidia’s A100 GPUs, which leaves China approximately four years behind the US (Erdil 2024). Meanwhile, Nvidia’s high-end H200 GPUs are estimated to hold a 3x training cost advantage over the best Chinese AI chips (Erdil 2024). Despite the US export controls, the best-performing Nvidia AI chips are continuously being stockpiled and smuggled into China (Swanson and Fu 2024). Nonetheless, the Chinese AI ecosystem remains significantly hindered by limited access to AI chips, which are essential in great numbers for large-scale model deployment and innovation capacity. Advanced chips are crucial for AI research and development as it is a compute-intensive process, and the remarkable advancements seen in recent years have largely been driven by leveraging increased computational resources (Sutton 2019)—in line with the “scaling laws” (Kaplan et al. 2020).

¹⁸ Frontier AI is a term for the most advanced and capable AI models, which can perform a wide range of tasks. For example, large language models such as OpenAI o3.

In late December 2024, the Chinese AI company released an open weight^{19,20} frontier AI model, DeepSeek-V3, which impressed the AI industry with its modest training cost and high performance across a range of benchmarks (DeepSeek-AI et al. 2024b; Wiggers 2024b). DeepSeek-V3 notably demonstrated that large language models (LLMs) can be produced on a substantially smaller budget using less compute by optimizing model efficiency through algorithmic improvements and meticulous engineering (Dai et al. 2024; DeepSeek-AI et al. 2024a, 2024b).²¹ Of interest to US officials, DeepSeek-V3 was trained on a cluster of 2048 Nvidia H800 GPUs—the downgraded version of the H100 in response to the October 2022 export controls—which were still legally exported to China until the October 2023 updates by BIS (Bureau of Industry and Security 2023). Remarkably, DeepSeek-V3 was trained for 2664 K GPU hours at an estimated cost of 5576 million USD—in comparison Meta’s contemporary LLaMa3.3 model required 39,300 K GPU hours on a H100 GPU cluster (meta-llama 2024; Patel et al. 2025).²² DeepSeek-V3 thus requires approximately 15 times fewer training compute hours—on downgraded AI chips—resulting in a remarkable reduction in training cost. DeepSeek’s efficiency gains extend beyond training and also lower the cost of inference²³ and model deployment. This is not only noteworthy as a technical achievement but also demonstrates that China has the AI talent to produce impressive innovations to mitigate the impact of US export controls and the restricted access to AI chips in China.

Despite DeepSeek’s progress, the US is still widely considered to be the leading AI nation, followed by China (Stanford HAI Staff 2024). The US

¹⁹Model weights are the trained numerical parameters that determine how the trained model processes input to produce output. In this context, the model weights are large computer files that are controlled by the export controls.

²⁰Strictly speaking, DeepSeek-V3 is not open source, despite occasionally being labeled as such, as the full source code is not released, e.g. training code and training data for transparency and reproduction. Instead, DeepSeek-V3 is released under the permissive MIT license as an “open weight” model, where the trained model parameters are made available for users to deploy or fine-tune.

²¹DeepSeek-V3 uses a model architecture, which includes mixture-of-experts with both shared and routed experts, which are balanced using an auxiliary-loss-free load balancing approach. The shared experts are used for every token, while only a subset of the routed experts are activated depending on the model input. V3 also applies multi-head latent attention to compress the key and value tensors in the attention mechanism, which reduces the key-value (KV) cache and memory usage. Several other techniques were also applied by DeepSeek engineers to make effective use of DeepSeek’s computing resources such as multi-token prediction to improve model efficiency during training; a mixed-precision framework using the FP8 data format; and efficient pipeline parallelism (DualPipe algorithm) that overlaps forward and backward passes to reduce idle GPU time (called “bubbles”) during training.

²²The exact production cost is contested as the reported figure of 5.576 million USD only accounts for the final training run, and therefore does not include cost related to research and development, infrastructure, staffing, etc. Analysts estimate that DeepSeek spent 1.6 billion USD on capital expenditure and 900 million USD on operating costs.

²³The process by which AI models produce an output, e.g. the text output by a large language model.

enjoys fundamental advantages as it designs the most coveted AI chips and is home to several frontier AI companies²⁴ that have pioneered the technology and developed the most widely used and best-performing models. These companies benefit from access to mature financial markets and abundant venture capital, which support a resource-intensive technology that is rapidly becoming a large-scale industry underpinned by massive data centers containing thousands of AI chips with enormous power demands. The significance of the US AI chip advantage relative to the PRC is underlined by the announcement of OpenAI's o3 model in December 2024. The o3 model represents an impressive improvement in AI capabilities, as it set a new high score on the ARC-AGI benchmark which assesses the general intelligence of an AI model by evaluating its ability to generalize to novel tasks beyond its training data by acquiring new skills (Chollet 2019, 2024). The model achieved this score through a technique for LLMs, where models are trained to “reason” by producing several separate paths of multiple intermediate steps of output and selecting the one deemed best as the final answer²⁵ (Wei et al. 2023). This marks a new paradigm in frontier AI, where the increase of compute to generate answers²⁶ leads to significant performance improvements (Chollet 2024).²⁷

Shortly thereafter, DeepSeek announced its own reasoning model called R1 model, which was built on top of DeepSeek-V3 and trained using reinforcement learning preceded by supervised fine-tuning of chain-of-thought data (DeepSeek-AI et al. 2025).²⁸ DeepSeek's models have attracted widespread attention due to their combination of open weight availability, permissive license, lower computing requirements, cost efficiency,²⁹ and advanced capabilities—sparking public debate on several key topics relevant to Washington and the US AI ecosystem (Gibney 2025; Patel et al. 2025). There were concerns about the technological lead and moat held by the US and its AI companies, and whether open weight models represented a better strategic approach for diffusing and expanding the US ecosystem (Parli 2025; Schmidt and Adjodah 2025). Questions were also raised about the utility of the export controls and the underlying assumptions about frontier AI, particularly the presumed requirements for large amounts of capital and computing resources. However, analysts argued that the chip controls still served a strategic purpose

²⁴ Historically, several transformative technologies for national security such as the internet, chips, GPS, and nuclear weapons were developed with strong involvement from the US government and Department of Defense. Frontier AI, however, is largely developed by private companies.

²⁵ The “chain-of-thought” technique combined with test-time search.

²⁶ Also called “inference scaling” or “test-time compute scaling.”

²⁷ OpenAI's o3 model was estimated to cost around 30,000 USD per task in its best-performing high-compute configuration on the ARC-AGI benchmark, a figure that was revised upward from an earlier estimate of 3000 USD.

²⁸ Reasoning could also be achieved without supervised fine-tuning using chain-of-thought data, but the outputs exhibited poor readability and language mixing.

²⁹ The API cost of DeepSeek-R1 is approximately 27 times lower than OpenAI's o1 model, which has resulted in speculation as to whether DeepSeek benefits from subsidies to artificially lower user pricing.

by slowing China's AI progress, although the inadequacies of the export controls undermined their desired impact (Lin and Heim 2025). In fact, DeepSeek CEO Liang Wenfeng also acknowledged that the activities of DeepSeek were constrained by limited access to AI chips: "Money has never been the problem for us; bans on shipments of advanced chips are the problem" (Schneider et al. 2024). This hardware bottleneck has also been suggested to limit DeepSeek's ability to deploy its models at scale (Allen 2025; Field 2025).³⁰

By contrast, the US enjoys a significant advantage as its semiconductor companies lead in cutting-edge AI chip technology—resulting in dominant supply chain positions—and US AI companies and hyperscalers host the vast majority of global AI compute capacity (Pilz et al. 2025). Access to advanced AI chips in large quantities will become increasingly critical as frontier models—which increasingly rely on more compute to improve model capabilities—are deployed more widely. Besides the test-time compute paradigm, frontier AI companies are pursuing research directions such as AI agents capable of acting more autonomously over longer time horizons, which further increases computational demand (Anthropic 2024). This convergence of trends—test-time compute, AI agents, and wider model deployment—means chip access increasingly grants competitive advantages in both AI development and deployment.

Although the US maintains its position as the global AI leader, China has narrowed the gap in the AI race considerably through impressive technological advancements. Yet, OpenAI CEO Sam Altman argued that being a fast follower is significantly less challenging than being a pioneer, and there is evidence suggesting that DeepSeek's models were trained using output generated by OpenAI's models³¹ (Wiggers 2024c). Nonetheless, DeepSeek's models represent significant technical progress in their own right given their combination of frontier capabilities and cost efficiency. Perhaps most significantly, DeepSeek-V3 suggests that the barrier to entry is lower than previously assumed, despite persistent questions surrounding the true production costs. The key questions are whether China can overcome the constraints imposed by the US, move beyond being a fast follower, pioneer novel AI capabilities, and establish itself as a competitive global AI ecosystem.

9 THE EMERGING ROLE OF AI IN NATIONAL SECURITY

The strategic importance of AI stems from its transformative potential across critical sectors, and especially its significance for national security (Schmidt et al. 2021). The US National Security Memorandum on AI from October 2024 emphasized the importance of frontier AI and articulated the Biden

³⁰ DeepSeek's website experienced an outage in January 2025, which was publicly attributed to cyberattacks. However, analysts suggest that DeepSeek failed to meet high user demand due to limited access to advanced chips.

³¹ DeepSeek allegedly used "model distillation," where a smaller and cheaper model is trained on outputs from a larger and more capable model.

administration's strategic thinking (The White House 2024a, 2024b). Biden's national security advisor Jake Sullivan outlined the three main areas of the Memorandum: "securing American leadership in AI, harnessing AI for national security, and strengthening international AI partnerships." He further underlined: "The stakes are high. If we don't act more intentionally to seize our advantages, if we don't deploy AI more quickly and more comprehensively to strengthen our national security, we risk squandering our hard-earned lead" (The White House 2024b). These ambitions require an expansion of the underlying enablers: data centers housing thousands of AI chips to provide vast amounts of compute, and energy sources to meet the enormous electricity demands of frontier AI (The White House 2024b, 2024c). As a result, an executive order was announced to expedite the buildout of AI infrastructure, which notably mandated support from federal agencies and authorized the leasing of federal sites to AI companies for data centers and clean energy sources (The White House 2025). Besides this physical infrastructure meeting the potential of AI also requires effective adoption, a strong AI-literate workforce, and coordinated action (Ding 2024).

Notably, the US-China Economic and Security Review Commission (2024) explicitly acknowledged the notion of an AI arms race and recommended that Congress "establish and fund a Manhattan Project-like program dedicated to racing to and acquiring an Artificial General Intelligence capability," and urged the US Secretary of Defense to designate as the highest national priority. This call to action reflects the expectations that AI will fundamentally transform defense capabilities in areas such as cybersecurity, information operations, and warfare (Payne 2021; Erskine and Miller 2024; Reuters 2024c; Scharre 2024; Bengio et al. 2025).³² The Pentagon's approach to AI outlines broad aims, including analyzing vast amounts of data sourced from intelligence and sensors to enhance situational awareness and decision support; enabling AI-assisted targeting and command and control; and, ultimately, compressing the kill chain (Hoehn 2022; U.S. Department of Defense 2022b; Hicks 2023; Zeff 2025). Reflecting these expectations and objectives, federal government spending on AI—particularly by the Department of Defense—has surged in recent years (Larson et al. 2024), with both public and private actors seizing this momentum and launching several initiatives to apply AI to the defense and security sector. For instance, the US Department of Defense (2023) established Task Force Lima to explore how to incorporate frontier AI into its operations, and the Replicator Initiative focuses on developing small, unmanned, autonomous, attritable weapons (Clark 2024; Tucker 2024). AI companies are acutely aware of this framing and the national security implications of their technologies, and are actively partnering with defense firms to support Washington's ambitions for

³² Critical questions remain regarding how AI will impact the offense-defense balance across different areas, with profound implications for national security.

AI (Pottinger and Amodei 2025; Anduril 2024; Wiggers 2024a; OpenAI 2025; Smith 2025).^{33,34}

At the same time, the US is closely monitoring the progress of AI implementation in the PLA, which can be difficult to assess due to the opacity of China's state of affairs. However, a US Department of Defense report (2024) states that the PLA is applying AI widely to develop algorithmic and network-centric warfare; autonomous and precision-strike weapons; autonomous vehicles; predictive maintenance and logistics; automated target recognition; and AI-supported wargames and training operations. However, China and the PLA still face significant obstacles, including the aforementioned limited access to cutting-edge AI chips and ongoing struggles in advanced semiconductor manufacturing (Nelson and Epstein 2022; Bresnick 2024a, 2024b). Furthermore, sociotechnical challenges such as the PLA's rigid command structure and organizational inflexibility are believed to complicate the application of AI in decision-making processes, regardless of China's technical capabilities in AI (Bresnick 2024b).

10 US FRAMEWORK FOR GLOBAL DIFFUSION OF AI CHIPS AND FRONTIER AI

The Biden administration viewed frontier AI as paramount for national security, and its actions to harness AI's potential were complemented by efforts to control access to this strategic technology for partners, allies, and adversaries. Biden released several AI initiatives during his lame-duck period (The White House 2025; Federal Register 2025b), with the sweeping Framework for AI Diffusion (FAID) as the most eye-catching policy. FAID was announced by BIS and explicitly outlined Washington's vision for AI globally (Federal Register 2025a). The objective of FAID was to retain global US leadership in AI; ensure secure diffusion of AI technology to trusted partners and allies; and deny adversaries access (Bureau of Industry and Security 2025a). FAID sought to achieve these goals by applying updates to the previous export controls on advanced chips and introducing export controls—including FDPR—on the model weights (parameters) of frontier AI.³⁵ This would allow the US to regulate global access not only to advanced AI chips but also to the development

³³In November 2024, Anthropic, Palantir, and Amazon Web Services partnered to integrate Anthropic's Claude models into Palantir's Maven Smart System used by US intelligence and defense agencies. The following month, OpenAI announced a partnership with Anduril to improve US defense systems.

³⁴This marks a notable shift from 2018, when Google employees protested over the ethical implications of developing AI for military applications, which led Google to not renew its contract with the Pentagon to support Project Maven by applying AI to analyze US drone footage. The contract was subsequently awarded to Palantir.

³⁵FAID only applies to closed source frontier models that are trained using more than 10²⁶ computational operations.

and deployment of frontier AI (Baptista et al. 2024; Gardizy 2024; Nevo et al. 2024).³⁶

In more detail, entities—such as AI companies—were categorized into three tiers according to the country of their headquarters: trusted allies and partners (Tier 1), arms-embargoed countries such as China (Tier 3), and the rest of the world (Tier 2).

Tier 1 was given several benefits and was the only tier permitted to deploy and train frontier AI. These countries must retain at least 75% of their AI chips within Tier 1 territory. However, this threshold was lower (50%) for US-based entities, which allowed for more flexibility and a wider international reach.

Tier 2 faced more elaborate restrictions and a capped limit on the number of imported AI chips. This ceiling could be increased through a verified end-user license, which required additional security measures to protect against tampering or theft of chips and AI models, and commitments to sever ties with any technology providers from Tier 3 countries, such as China.

Tier 3 was completely banned from purchasing AI chips, and also from training and deploying frontier AI. FAID thus addressed the concerns of Chinese companies training frontier models through cloud computing and establishing data centers outside of China (Baptista et al. 2024; Gardizy 2024; Ciccomascolo 2025). In fact, all cloud compute providers had to apply security measures to block Tier 2 and 3 from training frontier AI models (Heim 2025).³⁷

However, FAID was met with dismay from the private sector, which claimed it was designed without industry consultation. Companies also argued that FAID went beyond national security concerns and severely undermined US competitiveness (Finkle 2025; Glueck 2025). The reaction by the international community was equally astonished. Tier 1 included 18 members, with several notable omissions such as Israel being assigned Tier 2 status (Shilov 2025). Moreover, only subsets of NATO and EU members found themselves in Tier 1 and were thus fragmented by FAID, which left Tier 2 countries such as Poland fuming (Polska Agencja Prasowa SA 2025).

Tier 2 countries were essentially being treated as “swing states.” FAID presented Tier 2 nations with the choice between the US and Tier 3 nations, and did so by incentivizing the decoupling of technological ties to Tier 3 countries—thereby minimizing risks of diversion—by granting higher quotas for advanced chip imports. In this regard, Washington likely considered Microsoft’s business activities in the UAE—which was in this middle-tier—as a guiding example (Heim 2025; Winter-Levy 2024). Several Gulf States are looking to transition away from an oil-based economy and have identified AI as a strategic

³⁶ Although physical procurement of AI chips is important, there are alternatives for obtaining or developing frontier AI without possessing AI chips within one’s borders. One option is to steal frontier AI models through espionage or cyberattacks. Another option involves training frontier AI models through cloud computing, which Chinese companies like ByteDance and other entities on the Entity List have exploited.

³⁷ In this respect, FAID is especially advantageous to US cloud providers as they already comply with the security requirements.

priority, with both US and Chinese technology companies courting the Gulf States to commit to their respective digital ecosystems. Subsequently, Microsoft and G42—an AI company based in Abu Dhabi—announced data center projects in the UAE, which was a highly contentious topic in Washington due to the UAE’s relationship with China. The deal was eventually cleared by BIS after G42 committed to divest from Chinese companies; separate itself from Chinese technology suppliers such as Huawei; and implement security measures to block US adversaries from accessing its data centers (Reuters 2024b; Curi and Snyder 2024; Cornish and Wiggins 2024).

The strategy pursued by FAID directly opposed China’s Digital Silk Road—the digital arm of the Belt and Road Initiative—as the US dominates AI chip technology, whereas China’s AI chip industry has limited capacity to export AI chips, let alone meet demand of its own domestic AI sector (Miller 2024b). Therefore, FAID offered a strong proposition for countries to commit to the US AI ecosystem at the expense of China’s technological reach. The previous export controls on chip technology directly facilitated FAID as the SME restrictions impaired China’s advanced chip manufacturing and ability to provide a competitive alternative to US AI chips. FAID and the preceding export controls demonstrate how the US leveraged its technological superiority and resulting dependencies to enforce its vision of how AI should spread globally.

11 SCIENCE DIPLOMACY IN AN ERA OF TECHNOLOGICAL COMPETITION

This contribution demonstrates through several practical examples how science diplomacy is applied in the pursuit of strategic autonomy, technological leadership, and national interests in the context of great power competition (Gluckman et al. 2017). This stands in contrast to the popularized formulation of science diplomacy developed by the American Association for the Advancement of Science (AAAS) and the Royal Society (2010), which frames science as a universal language for bridging differences and addressing global challenges (Bollyky and Bollyky 2012). In recent years, practitioners of science diplomacy have noted the growing influence of national interests and suggested an updated taxonomy adopting a more pragmatic lens (Gluckman et al. 2017), arguing that these previous conceptualizations were ill-suited to provide an appropriate vocabulary and framework for this trend (Gluckman et al. 2017; Turekian and Gluckman 2024). Some scholars have also criticized the idealization and emphasis of science and technology as a unifier, arguing that it overlooks their competitive dimensions and associated geopolitical implications (Rungius and Flink 2020; Ruffini 2020).

Indeed, science diplomacy can also represent “actions designed to directly advance a country’s national needs” (Gluckman et al. 2017). The export controls leveraged by the US are largely enabled by its dominant positions in advanced semiconductors and AI technology, which allows the US to control and block their access to adversaries. This contribution shows how the US on

occasion acts unilaterally, when its technological and political might are permissive for such actions. In other cases, however, such as the export controls targeting SME and the reshoring of advanced chip manufacturing, the US relies on allies and partners to enforce restrictions effectively and provide their unique chip manufacturing expertise. In these examples, Washington has less room to maneuver unilaterally and instead depends on allies and partners that hold leading positions in technologies where the US is not dominant. On a global scale, the US has shown its ability and willingness to leverage its geopolitical influence and leadership in key technologies to advance its national interests by controlling the international diffusion of AI technology. To this end, the US employs AI technologies as bargaining chips, while simultaneously denying its adversaries the ability to obtain or use such AI technologies.

12 CONCLUDING REMARKS

This contribution presents an overview of the US AI and semiconductor strategy under the Biden administration and its underlying motivations, which are deeply rooted in AI as an emerging technology considered crucial for national security coupled with the perception of China as the predominant US pacing challenge (Schmidt et al. 2021; U.S. Department of Defense 2022a; The White House 2024a). The US-China AI race demonstrates that geopolitics and emerging strategic technologies are inextricably linked and reveals their substantial mutual influence. The general-purpose nature and capabilities of AI promises to transform numerous strategic domains, and its emergence and potential have far-reaching consequences for global affairs. In the current international arena, this framing of AI has drawn geopolitical rivals into fierce competition, motivated by AI's promise to empower the frontrunner with economic, political, and military advantages.

At the same time, the competition between great powers is shaping the ongoing evolution of technology as tensions are spilling into the realm of science and research with negative consequences for scientific progress and international collaboration (Xie et al. 2023; Conroy 2024; Jia et al. 2024; AlShebli et al. 2024). Moreover, the AI and chips race affects the global diffusion of technologies and thus the scientific environment for further progress of AI (DeepSeek-AI et al. 2024b; Federal Register 2025a). Geopolitical competition and conflict also accelerate the application of AI in defense and security as national security concerns affect how companies and governments approach AI (U.S. Department of Defense 2023, 2024; Tucker 2024; U.S.-China Economic and Security Review Commission 2024; OpenAI 2025; Pottinger and Amodei 2025; Smith 2025). Currently, this influence is seen vividly in the ongoing war between Ukraine and Russia, where the contours of a new form of autonomy-augmented warfare are gradually appearing as the existential threat faced by Ukraine has spurred the adoption of emerging technologies. AI is incorporated into Ukraine's DELTA System—a situational awareness and battlefield management system—and is leveraged in the ongoing cat-and-mouse game in

drone warfare that increasingly involves autonomy, and for which fast innovation cycles are occurring in workshops and on the battlefield with close cooperation between engineers and military personnel (Barnes 2024; Bondar 2024a, 2024b; Manson 2024).³⁸

Despite the ongoing contest for AI leadership, there are still important opportunities for science diplomacy to address global challenges. In parallel with the competition for technological innovation and leadership, the rapid evolution and transformative potential of AI are accompanied by profound concerns about the risks AI poses to international security and stability (Byman et al. 2023; Puscas 2023; Bengio et al. 2025). These risks have been recognized by both China and the Biden administration (The White House 2023c, 2024b; Bresnick 2024a; Wong 2025; The Economist 2025), and dialogue addressing these concerns has occurred through both Track 1 and Track 2 diplomacy (Palma et al. 2023; The White House 2024d; Pinghui et al. 2024; Financial Times 2024; Guest 2024; Singh 2025), as well as engagements in international forums (GOV.UK 2023; Mishra 2024). Furthermore, a geopolitically tense environment accelerates the application of AI in defense and security, posing urgent legal, ethical, and technical questions and potentially increasing the risks AI presents to global stability. These challenges make diplomatic engagements all the more significant, and notably, Biden and Xi reached an agreement in 2024 to exclude the application of AI in decision-making regarding nuclear weapons (Renshaw and Hunnicutt 2024). While Track 1 engagements were undoubtedly also motivated by developing a joint framework for the ongoing US-China competition, these exchanges also offer an opportunity for dialogue that can establish guardrails and address the challenges associated with AI's progress and adoption. The same technologies that drive great power rivalry carry risks for global security and stability that no nation can address alone. This reaffirms the imperative of science diplomacy and international cooperation to advance the global common good.

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³⁸ Following the Russian invasion of Ukraine, the US reportedly supported Ukraine by deploying its AI-enabled Maven Smart System to identify Russian military assets to assist Ukrainian targeting operations. The Maven Smart System simultaneously underwent iterative improvement under real battlefield conditions.

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Navigating Emerging Trends in Science Diplomacy: Insights from German and US Partnerships

Nils Koebis and Priya S. Nayar

I INTRODUCTION

We are living in a world characterized by rapid technological disruption. Systems powered by artificial intelligence are increasingly affecting people's lives. In the workplace, AI is transforming or risking to replace many professions (Frank et al. 2019). In education, AI systems have already changed the way students learn and are learning and being evaluated (Seo et al. 2021). But also in the private sphere, AI systems are forming ever more intimate relationships with people (Starke et al. 2020). Besides, AI quantum computing is breaking new ground (Binns 2018), with large tech companies developing machines of unprecedented computing speed that could revolutionize data processing in fields such as cryptography and drug discovery.

Science diplomacy has emerged as a vital instrument to address such global challenges. Science diplomacy, at its core, operates at the intersection of scientific collaboration and diplomatic engagement, facilitating dialogue across borders to resolve shared global problems (Fedoroff 2009). As competition in emerging technologies intensifies, science diplomacy provides a neutral platform where nations, corporations, and institutions can align efforts in research and innovation. For instance, technology diplomacy can serve as a platform to facilitate global alignment on AI policy and governance (Feijóo et al. 2020). It helps bridge the gap between scientific advancements and policy, fosters

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international collaboration on complex issues, and ensures equitable access to emerging technologies.

A prime example of science diplomacy in action is the University Alliance Ruhr (UA Ruhr), an alliance of three German universities: TU Dortmund University, Ruhr University Bochum, and the University of Duisburg-Essen. UA Ruhr is a best practice example of how regional university alliances can serve as crucial actors in advancing science diplomacy, fostering international cross-sector collaboration and addressing global challenges through shared scientific endeavour. Such alliances position universities as change-makers, creating pathways for knowledge exchange that transcend national borders and directly engage with the disruptions shaping our world.

By fostering transatlantic partnerships, particularly in areas like AI, technology transfer, and entrepreneurship, UA Ruhr actively demonstrates science diplomacy in action and how it can be used to confront the ethical, regulatory, and governance challenges posed by rapid technological advancements.

Prof. Dr. Tessa Flatten, Vice President, International, TU Dortmund University, underscores the importance of foundational principles in successful research partnerships. She emphasizes that successful research partnerships “thrive on trust, mutual understanding, and a balanced exchange of knowledge and highlights the importance of both learning from and contributing to each other’s expertise, which fosters productive collaborations.” This philosophy is central to UA Ruhr’s approach to international partnerships where the goal is not just to exchange insights but also to offer a platform for active dialogue and engagement, creating a reciprocal environment (Flatten 2024). By being a regional alliance, the UA Ruhr provides a strong starting point as an attractive opportunity for collaboration for international partners.

This case study explores UA Ruhr’s role in advancing the strategy and practice of science diplomacy through multilateral and bilateral cooperation, illustrating the crucial role of institutions of higher education research and regional alliances in shaping the future of innovation in an era of technological disruption.

This case study adopts a qualitative approach, employing semi-structured interviews. Key stakeholders from both UA Ruhr and its US counterparts have been interviewed to explore the challenges and opportunities of transatlantic cooperation in emerging technologies. These interviews focus on the governance of AI, technology transfer, and the role of entrepreneurship in fostering international collaboration.

AI is at the forefront of technological disruption, spurring both competition and cooperation between nations. The global race for leadership in AI, particularly between countries like the United States, Germany, and other emerging powers, highlights the necessity of establishing collaborative frameworks through science diplomacy. AI, similar to science diplomacy, offers opportunities for joint ventures that transcend political boundaries, bridge geopolitical divides, and foster collaboration between nations with conflicting interests. As these technological innovations evolve, the ethical implications, cybersecurity

concerns, and growing digital divide become central issues that require international consensus and regulation.

Germany and the United States are among the global leaders in AI research and development, with well-established scientific infrastructures. Their collaboration, mainly through platforms like UA Ruhr, that is, active models of science diplomacy in action, accelerates research, informs policy making, strengthens science and innovation ecosystems, bridges gaps between nations, and addresses global technological challenges. In this context, science diplomacy becomes the framework through which AI ethics, cybersecurity, and equitable access to technological advancements are negotiated globally. By fostering international dialogue, science diplomacy can ensure that technological innovations are governed responsibly and equitably, bridging gaps between regions and sectors.

2 UA RUHR: A MODEL FOR SCIENCE DIPLOMACY IN ACTION THROUGH REGIONAL, GLOBAL MULTILATERAL, AND TRANSATLANTIC COOPERATION

The UA Ruhr stands as a model of how regional collaborations provide the model for science diplomacy in action and can extend into impactful transatlantic partnerships. Initially formed to pool resources and amplify research impact within Germany, the alliance has expanded into a network of international academic cooperation and partnerships, particularly with US institutions like Stanford University and MIT (e.g. <https://lamarr-institute.org/transfer/>). This collaborative/cooperative model facilitates global dialogue by providing transnational engagement mechanisms, as well as promotes the development of new technologies and ecosystems particularly in AI and data science, through the sharing of knowledge, data, and resources.

According to Emmanuel Müller (2024), Director of the Research Center Trustworthy Data Science and Security, the success of these collaborations lies in establishing “symmetric partnerships.” He emphasizes, “The key word there is symmetric, symmetric partnership. And that’s exactly what we also thought in the design decisions for the research center, to not have one partner be a service for the other, but it should be symmetric from both sides.” This philosophy of balanced collaboration ensures that both partners contribute equally to research, which, in turn, creates sustainable, long-lasting partnerships (see <https://rc-trust.ai/about/network>).

In its approach to AI, UA Ruhr addresses both the potential of the technology and the ethical challenges associated with it. The Research Center Trustworthy Data Science and Security (RC Trust) is an exemplary initiative that focuses on these challenges. As Müller (2024) notes, “The design decision was exactly having the strength from every university ... statistics and computer science, both under the umbrella of this AI and data-driven science.” This interdisciplinary collaboration integrates fields like statistics, cybersecurity, and

cognitive science to address critical issues such as AI governance, fairness, and accountability.

Through collaborations with US institutions, the UA Ruhr provides a platform for active engagement in science diplomacy and addressing pressing global challenges related to AI. These partnerships are not just academic endeavors but are proactive frameworks vital in promoting technological implementation that can be directly applied in industry and policy. By bridging theoretical research with practical applications, UA Ruhr demonstrates how it is a model for science diplomacy within the current global participation frameworks and can foster innovation in AI and facilitate its responsible deployment.

Vice Provost Lisa Getzler (2024), Lehigh University, echoes the point on interdisciplinary collaboration, "...the more perspectives, the more diversity among our population, the greater the chance for innovation and the greater the opportunity to address global problems in an entrepreneurial way."

3 TECHNOLOGY TRANSFER AND ENTREPRENEURSHIP: CATALYSTS FOR SCIENCE DIPLOMACY

One of the core pillars of UA Ruhr's transatlantic cooperation is technology transfer. The collaboration between academia and industry plays a crucial role in bridging scientific advancements with practical applications. Science diplomacy serves as the framework for international cooperation, allowing both academic institutions and industries to collaborate in areas such as AI commercialization and the creation of innovation hubs. Through a focus on entrepreneurship, UA Ruhr facilitates not only academic research but also the commercialization of new technologies with global implications.

Emmanuel Müller (2024) highlights this dynamic, explaining how partnerships with industry can shape the direction of academic research: "We are more in the position of filtering out with whom we collaborate ... it is this kind of symmetric collaboration. My research topic number one at the moment was derived by such a collaboration." This demonstrates how UA Ruhr is in sync with the needs of research partners and actively leverages science diplomacy mechanisms to foster global industry partnerships, ensuring that academic projects have practical value and are responsive to the needs of industry within an international context.

The RC Trust plays a central role in this process, fostering collaborations that emphasize AI's ethical and practical applications. As Müller (2024) notes, partnerships between academia and industry are essential for pushing the boundaries of innovation: "In most cases, I think it is this kind of symmetric collaboration because in my case, my research topic ... was derived by such a collaboration. We made several PhD theses out of that challenge, and we are still publishing and collaborating with industry on anomaly detection." This statement highlights the continuous loop of innovation that arises from strong cross-sectoral international partnerships, where both academia and industry benefit equally from the collaboration.

4 LONG-LASTING COLLABORATIONS AND THE ROLE OF PEOPLE IN SCIENCE DIPLOMACY

A key element of successful science diplomacy is the establishment of long-lasting collaborations. As Müller (2024) explains, sustainable partnerships are those that last over many years and evolve over time: “There are other collaborations, for example, with the physics department where there is both gain from each other ... very big scientific discoveries out of this ... over more than 10 or 12 years.” Such enduring partnerships allow for deeper exploration of complex problems, particularly in emerging fields like AI.

Sustained long-term collaboration is especially important in the context of UA Ruhr’s transatlantic partnerships. These enduring relationships and cultural exchanges between Europe and the United States serve as a cornerstone of science diplomacy, fostering mutual understanding, enriching research, and allowing for the integration of different perspectives. Müller (2024) emphasizes the importance of combining diverse approaches, such as the theoretical focus in Europe and the practical, tech-driven approach in the United States: “We bring in cultural differences ... a new research field in our community.” This diversity of thought leads to innovation and the creation of new fields of research, such as fairness in anomaly detection, demonstrating the value of transatlantic cooperation.

Lehigh University’s Vice Provost for Entrepreneurship, Lisa Getzler (2024) emphasizes the importance of cross-border collaborations, particularly between the United States and Germany, in tackling complex global issues. She explains, “While each country has its own laws, policies, and challenges, these differences shouldn’t prevent us from working together. To make progress as a global community, we must collaborate across borders and find entrepreneurial solutions to our shared problems.”

Building on this idea of global cooperation, NYU’s Associate Vice Provost for Research Planning and Analysis, Dr. Nina Gray, envisions a future of science diplomacy that is increasingly reliant on strategic, network-based collaborations. According to Dr. Gray (2024), “The future of science diplomacy will require a more strategic, network-based approach, where collaborations between countries and institutions are facilitated through interconnected networks, rather than isolated partnerships. This will allow us to tackle global challenges more effectively, as we pool resources and expertise to address issues like climate change, health, and emerging technologies.”

Moreover, Müller (2024) highlights that successful collaborations depend not just on institutional relationships but also on the people involved: “I think it’s the people that is still missing in the argument. I think you have to be somehow scientific friends with each other.” He stresses the importance of personal relationships and scientific camaraderie in ensuring that collaborations are not just productive but also enjoyable and sustainable. Institutional actors such as UA Ruhr provide the platform and knowledge-based diplomatic pathways to emphasize the focus on people, especially early-career researchers, fostering a

collaborative environment that supports both scientific discovery and career development.

5 CONCLUSION: THE FUTURE OF SCIENCE DIPLOMACY IN A DISRUPTED WORLD

As the world faces increasing technological disruption, science diplomacy will continue to play an essential role in fostering international collaboration, global cooperation, network-based collaborations, as well as cross-border dialogue. The UA Ruhr's successful model of regional and transatlantic partnerships exemplifies this concept of institutions as drivers of scientific engagement and global collaboration that provide the science diplomacy frameworks and the pathway to address both the opportunities and challenges posed by AI and other emerging technologies, by enabling collaborative entrepreneurial solutions to shared problems.

We have found through our global cross-border partnerships that UA Ruhr partners favor people-to-people relations, stressing values of trust and networks (Getzler; Gray; Flatten; Müller 2024). This is in line with broader global science diplomacy initiatives that foster cross-border understanding and collaboration through direct trust-based interactions between individuals. Such initiatives are exemplified by platforms like the Science Diplomacy Forum convened by DWIH New York (2025). By facilitating technology transfer and knowledge exchange, promoting entrepreneurship, and addressing ethical concerns, UA Ruhr's collaborative initiatives demonstrate how science diplomacy can act as a transformative force in a multipolar world.

Through the lens of AI ethics, cybersecurity, and equitable technological advancement, UA Ruhr's model highlights the importance of balanced, long-term, and diverse partnerships. As Emmanuel Müller (2024) notes, "There is a sweet spot where both parties have something to gain from it ... you meet on equal footing so that you don't have from the get-go a very asymmetric relationship." This principle of symmetry and global transnational engagement underscores the success of UA Ruhr's partnerships and their role in shaping the future of science diplomacy.

Ultimately, as AI and other technologies continue to evolve, science diplomacy will be critical in ensuring that these advancements are governed ethically, equitably, and responsibly on the global stage.

Key Takeaways

- UA Ruhr as a model for how regional collaborations and institutions provide the ecosystem for promoting science diplomacy transcending national borders.
- Tech transfer within the knowledge-based economy and entrepreneurship is a core component for science diplomacy.

- Importance of trust and reciprocity to foster long-term international collaboration.
- People-centered approach as institutional partnerships alone cannot drive innovation.

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Space Diplomacy and International Collaboration

Francisco Del Canto Viterale

1 INTRODUCTION

The space sector has consistently been a pioneering domain within the scientific, technological, and innovative (STI) realms, playing a substantial role in global politics. With the launch of the A-4 (V-2) in June 1944, the first known human-made object to reach outer space, space activities became a pivotal aspect of international relations. During the Cold War, the United States and the Soviet Union engaged in a highly competitive geopolitical race in space. The space race included several notable space milestones: the launching of the first artificial satellite in 1957, the first animal into space the following year, the first human into space in 1961, the first multi-crew mission in 1964, the first lunar landing in 1969, and the establishment of the first space station in 1971. These space milestones were significant scientific achievements, but they also played an important geopolitical role in the Cold War. They represented a critical technological sector where both superpowers were engaged in competition, as well as an instrument of negotiation and diplomacy.

Since the end of the twentieth century, the international order has undergone a process of systemic-level transformations, in which STI, and particularly space, have become pivotal factors. Over the past three decades, a scientific and technical revolution, coupled with the emergence of increasingly complex global challenges, has led to a profound transformation of the international system. In parallel, the space sector has experienced significant changes in the period following the Cold War. In essence, we have witnessed a transition from

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a bipolar and relatively simple space system in the twentieth century to new space age in the twenty-first century that is more complex due to the emergence of new space actors (states and non-states), new types of interactions (from cooperation to competition and conflict), and new processes and megatrends in space (commercialization, militarization, privatization, planetary defense, etc.) that have a significant impact on the entire world system (Del Canto Viterale 2023, 1).

The concept of space diplomacy, which applies the principles of science diplomacy to the expanded exploration of space, is not a new phenomenon. Since the origins of space activities in the 1950s, space has been utilized as a strategic diplomatic instrument by governments, resulting in constructive outcomes such as the Apollo/Soyuz Test Project (1975), the Shuttle/MIR project (1992), and the International Space Station (1998). In the context of the twenty-first-century geopolitical and geoeconomics landscape, space diplomacy has assumed a renewed significance as a powerful tool for mitigating geopolitical tensions and fostering international cooperation.

In light of the preceding considerations, the major research question of this chapter is: How can space diplomacy as a form of science diplomacy help address the challenges of a rapidly changing global order? The primary hypothesis is that space diplomacy will assume a central role in serving to reduce geopolitical tensions and cultivate trusted relationships among states.

The profound transformations in the space domain have created the need for novel theoretical and methodological approaches that address the role of space diplomacy within the international system. This chapter employs an analytical approach to examine how space diplomacy can facilitate the integration of world politics, technological advancement, and international cooperation. The result is a comprehensive examination of the evolution, significance, and prospective trends of space diplomacy and their implications for the twenty-first-century international system.

This chapter is divided into five sections. The second section offers an explanation of the nature and import of space diplomacy, as well as a concise examination of how space diplomacy facilitates international cooperation. The third section presents an analysis of the significant transformations that have occurred within the international, technological, and space systems over the past few decades. The fourth section addresses the potential for space diplomacy, providing an analysis of the new roles that space diplomacy is assuming within the twenty-first-century international system. The fifth and final section presents a series of conclusions.

2 SPACE DIPLOMACY

Conceptual Definition of Space Diplomacy

Space diplomacy is not a novel phenomenon. Indeed, it has played a significant role throughout the twentieth century, particularly during the Cold War and

subsequently in the post-Cold War era, functioning as a reliable instrument of negotiation among international actors.

In the context of science diplomacy, space diplomacy represents a specific approach that uses issues related to outer space to foster positive relationships between actors engaged in addressing common problems. The scientific community transcends national boundaries in seeking solutions to problems of common interest (Haas 1992, 2). Consequently, these channels of scientific collaboration can contribute to new cooperative relationships among international actors. The domain of space is a notable exemplar, wherein cooperative activities have yielded positive outcomes.

For the purposes of this research, space diplomacy is defined as a specific type of science diplomacy. In this sense, science diplomacy is understood as the use of scientific interactions among nations to address the common problems facing humanity and to build constructive, knowledge-based international partnerships (Fedoroff 2009, 9). Therefore, space diplomacy is the application of science diplomacy to the expanded exploration of outer space trying to reach a consensus among the major international actors.

The majority of literature on space diplomacy defines the phenomenon in three distinct ways:

1. It is defined as a diplomatic tool that states and non-state actors employ to pursue their legitimate national or particular interests. In this sense, it is viewed as a diplomatic apparatus that facilitates the accomplishment of foreign policy objectives and the growth of national space capabilities (Namdeo and Vera 2023).
2. It is considered a method of interaction, communication, and understanding among international actors. As a process of dialogue conducted by actors in pre-existing or emerging contexts, structures, institutions, or venues that can result in outcomes of cooperation or conflict on a given space topic (Davis Cross and Pekkanen 2023, 194).
3. It is also perceived as an instrument to reach agreements and create mechanisms of cooperation among different stakeholders. This instrument facilitates negotiations among space actors that allow the development of different formal and informal mechanisms to ensure peaceful coexistence in outer space (UNOOSA 2024).

Each of these three theoretical conceptualizations of space diplomacy delineates a particular aspect of the multifaceted and intricate role that space diplomacy plays within the international system.

In the contemporary international context, traditional diplomacy is undergoing substantial and rapid transformations that are profoundly reshaping the very essence of diplomacy as it has traditionally been understood (Ton 2024). Consequently, science diplomacy and space diplomacy have emerged as non-traditional forms of diplomacy, assuming an increasingly prominent role in the international system.

Space Diplomacy and International Cooperation

All actors within the international system utilize both formal and informal mechanisms to facilitate the communication of norms, persuade others of the merits of their perspective, and engage in bargaining to achieve a successful compromise.

The utilization of science diplomacy within the international system has enabled international actors to reach agreements in the space domain in a multitude of forms, with a diverse range of stakeholders across multiple sectors, pursuing a variety of objectives. As a part of science diplomacy, space diplomacy has proven an effective means of bridging the gaps between parties with opposing views and developing mechanisms to ensure the long-term sustainability of these agreements. In the space domain, a plethora of mechanisms of space diplomacy are employed by actors in order to pursue international cooperation. Such mechanisms include:

- *National space policies*: domestic space policies are being created or updated by all space powers, as well as emergent, middle, and smaller powers. These policies include explicit mechanisms of international cooperation in space and the utilization of space diplomacy for the purposes of the pursuit of national interests (United States, China, Turkey, Russia, etc.). (U.S. Department of Defense 2023).
- *Intergovernmental Organizations*: international organizations constituted by states, with a legal personality separate from their member states, that can enter into legally binding agreements (United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)).
- *Intergovernmental regulatory binding agreements*: these are formal, legally enforceable agreements between two or more governments that establish rules, standards, or cooperative frameworks for mutual issues (Outer Space Treaty).
- *Sectorial bilateral and multilateral agreements*: several intergovernmental organizations concentrate on particular objectives that have demonstrated less ambitious but more efficient roles in the space system (International Telecommunications Union (ITU), International Civil Aviation Organization (ICAO), UN Conference of Disarmament).
- *Regional organizations*: a growing process of regionalization of space activities that foster cooperation with countries in close geographical proximity (European Space Agency (ESA), Asia Pacific Space Cooperation Organization (APSCO), etc.).
- *Bilateral/Multilateral Agreements*: these initiatives are less formal and more flexible than past intergovernmental efforts, particularly in the absence of binding agreements (Artemis Accords, BRICS, ILRSCO, etc.).
- *Non-Governmental Organizations (NGOs)*: these actors operate independently of government influence and pursue diverse objectives (International Astronautical Federation, International Academy of

Astronautics, International Astronautical Federation, Mars Society, Secure World Foundation).

These mechanisms are employed by a diverse array of space actors, including states and non-states, with a multitude of interests and goals across multiple arenas of action (international, regional, national, and local).

3 NEW INTERNATIONAL, TECHNOLOGICAL, AND SPACE CONTEXT

As has been previously stated, space diplomacy is not a novel phenomenon. However, the contemporary context of a transitioning international system, an unprecedented technological revolution, and the advent of a new space age present novel challenges for those engaged in space activities. In this new global context, space diplomacy, as an instrument for cooperation, must adapt to new circumstances, actors, agendas, trends, mechanisms, and national and sectorial interests.

A New International System

In the latter decades of the twentieth century, the international system underwent a substantial transformation, driven by a confluence of global processes that operated in parallel within the world order, resulting in a significant reconfiguration of the international system. The end of the Cold War and the collapse of the Soviet Union (Halliday 2000), new trends of globalization and deglobalization (Haass 2020; Rodrik 2021), the persistent erosion of the role of the nation-state (Strange 1996; Habermas 2000), the evolution toward a new stage of capitalism (Stiglitz 2002; Porter 2011), and the development of an unprecedented scientific and technological revolution (Schwab 2016, 2018; Deudney 2018) are among the most significant developments that have shaped the international system in recent decades.

The dissolution of the Soviet Union in December 1991 signified the formal conclusion of the Cold War and the termination of the bipolar international order that prevailed during the latter half of the twentieth century. Subsequently, the international system has undergone a transition, accompanied by a reconfiguration of power relationships and a repolarization of the world order. The core of this process is the shift toward a new order of the international system, in which political power is redistributed due to the emergence of new nation-states with geopolitical aspirations (such as the European Union, China, and India) and the formation of a more multipolar international system.

A considerable number of scholars, experts, and prominent figures are hypothesizing about the profound shift in global power dynamics in the contemporary international system. This transition has been described as a potential shift from U.S. leadership to Chinese dominance (Allison 2015), a return

to multipolar world order (Walt 2023), or a potential re-emergence of a bipolar system with China instead of Russia (Brooks and Wohlforth 2023).

An Unprecedented Technological Disruption

It is an irrefutable fact that space has played a pivotal role in the twentieth century as a pioneering technological sector, exerting a considerable influence on the power dynamics of the international system. The space race between the two superpowers precipitated the development of novel technological applications in the space domain, thereby enabling the attainment of remarkable objectives in outer space, including artificial satellites, lunar and Mars missions, and space stations among many others.

In recent years, the acceleration and expansion of the technological revolution has rapidly changed the international landscape. The expansion of scientific knowledge, the emergence of novel technologies, and a substantial number of noteworthy innovations and advancements have amplified the scale and intricacy of international transformations. Some experts characterize the impact of STI in this new world order as a “*turbo change*” (Deudney 2018).

In the transition to a new international order in the twenty-first century, space has become an increasingly significant factor in world politics. This is due in large part to the remarkable technological advancements and applications in the space industry, which have brought space to the forefront of the global agenda. Contemporary life is profoundly dependent on space services, which support critical sectors such as the military, utilities, aviation, and emergency communications. The technological applications and societal impacts of space are multifaceted, ranging from telecommunications, GPS, and providing accessible internet connections to millions of people worldwide to prevent natural disasters, to the use of cell phones, ATMs, or food delivery.

The advent of novel technologies, including 3D printing, robotics, artificial intelligence, and nanotechnology, has precipitated a paradigm shift in the realm of space technology, paving the way for unprecedented opportunities in space exploration and economic prosperity. Governments and private companies are allocating increasing resources to the space domain, developing new space-related technologies that facilitate expanding human presence in the final frontier. The profound geopolitical, social, economic, and technological implications of space have firmly established it as a pivotal technological sector within the contemporary dynamics of the international system in the twenty-first century (Schwab 2018).

The Dawn of a New Space Age

The profound changes occurring within the international system are also having a significant impact on the development of a new space age. Since the turn of the twenty-first century, there has been a profound transformation in the global space system, evolving from a relatively simple and bipolar structure to

a more complex and multifaceted one (Del Canto Viterale 2023). The advent of the new space age is the consequence of substantial and profound alterations to the fundamental parameters that govern the space sector.

First, there has been a notable increase in the number of actors engaged in space activities, including both states and non-states. At the present time, several new powers and emerging countries are engaged in competition for control of outer space. The most prominent of these are China, India, France, Germany, and Japan, but regional powers such as Iran, Brazil, Turkey, and the United Arab Emirates are also involved. The competition is no longer limited to scientific and military purposes; it has expanded to include economic and commercial interests, which are becoming increasingly dominant. At the same time, there has been a growing number of non-state actors involved in space activities, including private companies, international organizations, NGOs, think tanks, and others. The gradual but persistent entry of private companies into the space domain over the past three decades has increased exponentially, transforming the role of the private sector in space activities (Weinzierl 2018). Since the beginning of the twenty-first century, private companies such as SpaceX, Blue Origin, and Virgin Galactic have transformed the space industry through technological advancements in numerous domains, including launch systems, communication networks, and space exploration. These companies are collaborating with national governments while concurrently pursuing their own objectives. For instance, SpaceX has unveiled plans to establish a Red City on Mars by the year 2050. This phenomenon, while primarily observed in the United States, where the private sector has historically exhibited dynamism and innovation, is also evident on a global scale. The proliferation of space companies in countries such as India, China, and the European Union serves as a testament to the global nature of this trend.

Second, there has been an observable increase in the level of competition and conflict within the space sector in recent years. The current geopolitical landscape, marked by events such as the invasion of Ukraine, the conflict in the Middle East, tensions on the Korean peninsula, the political instability of Venezuela, and the status of Taiwan, is giving rise to a more conflictive international order, which is in turn affecting the space domain. As a result, there is a growing concern about the militarization and weaponization of outer space (Moltz 2019a, 2019b; Pankova et al. 2021), as well as the increasing military budgets and the creation of new military organizations to address space security and national defense for the majority of space powers (Dolman 2002, 2012; Moltz 2019b; Colucci and Carlson 2021). Space diplomacy plays a significant role in mitigating the aspirations of various space actors to augment the military presence in space and identify common ground for the peaceful exploration of outer space.

Ultimately, as a consequence of these preceding systemic alterations, we are confronted with a novel space agenda that encompasses concerns such as the expansion of outer space and technological advancement with profound geopolitical and economic ramifications, the utilization and commercialization of

outer space resources, the expanding role of the private sector in the space industry, and the flourishing space economy, the proliferation and elevated risk of space debris, and the intensifying dynamics of competition and conflict that have emerged in the space sector in recent years (Weinzierl 2018; Sommariva et al. 2020; Peeters 2021).

4 THE ROLE OF SPACE DIPLOMACY IN INTERNATIONAL COOPERATION

Historically, space diplomacy has played a significant role as a mechanism of international cooperation. Major actors in the international system have recognized that outer space is a domain where states with disparate national interests can identify common ground and develop cooperative relationships. This has positioned space diplomacy in a unique role as an instrument of cooperation.

Motivations for International Cooperation

As part of a long-standing theoretical and disciplinary discussion, the discipline of International Relations (IR) has addressed international dynamics as a dichotomy between conflict (war) and cooperation (peace). A dominant school of thought in IR, realism, has focused its analysis on the concept of the international order as an anarchic system. In essence, this system is characterized by the primary goal of states to maximize their own security, with cooperation being regarded as a tactical strategy (Kaufman 2018, 46).

Since the beginning of the space race in the context of the Cold War, those with a realist perspective have pursued to identify the optimal strategies for space powers to deal with the new relevance of outer space, to enhance their influence in the international arena. In an anarchic international system, where states must rely on their own capabilities to survive and where the resolution of disputes is primarily determined by power, the extraterrestrial dimension emerged as a strategic competitive scenario. A considerable number of experts have postulated that outer space will evolve into a new battlefield among major powers. In this context, realists argued that control of outer space will ultimately determine the distribution of power and influence on the international system (Dolman 1999). In 1999, Everett Dolman introduced the term “*astropolitik*” to describe a realist perspective on state competition in outer space, particularly in contrast to the development and evolution of a legal and political framework for space utilization. Orbits, regions of outer space, and launch sites are described as geopolitically vital assets over which states inevitably will engage in strategic competition for control (Dolman 2012; Moltz 2019a; Colucci and Carlson 2021).

In contrast, the international liberal school does not view the world as being in a state of permanent conflict between countries. Rather, it assumes that states and peoples should be aware of their common objectives, which can be reached through effective international cooperation rather than unilateral

efforts. In light of this line of reasoning, the liberal approach posits that the effective control of outer space by a single state would give rise to a negative planet-wide hegemony. This is in contrast with the potential for peaceful use of outer space and the necessity of maintaining a balance between superpowers, as well as the creation of institutions and regulations that provide a forum for discussion. To promote international cooperation, liberalism emphasizes the significance of space law, space regimes, space organizations, and space cooperation—elements that transcend national interests (Keohane and Nye 1971).

While liberals and realists both perceive the international system as anarchic and view actors as inherently self-interested, liberals nevertheless espouse the possibility of cooperation rather than purely competitive action through unilateral means (Broniatowski and Sabathier 2006; Knipfer 2017). The ability of states to cooperate in space can be attributed to several factors. First, such collaboration can reduce the cost of space-related activities by sharing the financial burden with other governmental entities. Second, the prestige and influence derived from such cooperation can be significant including “soft power.” Third, the establishment of a set of standardized behaviors can be beneficial to create a common framework. Finally, the political stability created by the commitment to other actors can be also a key motivator.

The history of the space age demonstrated a long-standing tradition of international cooperation in space activities, which confirmed the genuine interest of actors to collaborate within the international system. For decades, space diplomacy has served as an instrument to establish significant provisions regarding the reduction of threatening developments in space and the attainment of global commitments.

The Contribution of Space Diplomacy to International Cooperation

Over the twentieth century, the practice of space diplomacy has proven to be an effective mechanism for international cooperation among states. In light of the aforementioned experience and the significant alterations that have occurred in the international and space contexts over the past few decades, it appears that space diplomacy has assumed a more pivotal role in the present era than ever before. The argument presented here leads to the major research question of this chapter: How can space diplomacy as a form of science diplomacy help address the challenges of a rapidly changing global order? The following section presents evidence to support the main hypothesis of this chapter, which is that space diplomacy will play a crucial role in the twenty-first-century international system serving as a conduit for the reduction of geopolitical tensions, the establishment of reliable relationships, and a significant contributor to the cooperative governance of the international system.

Reduce Tension and Develop Positive Engagement

As the history of science diplomacy showed, the universality of scientific methods can be leveraged to mitigate tensions and foster constructive engagement

among international stakeholders with historically challenging or constrained relationships in high-stakes contexts. The evolution of space activities demonstrates numerous instances where space diplomacy has fulfilled this function.

In the context of the Cold War, the two superpowers were able to utilize space as a strategic asset in diplomatic negotiations, effectively reducing tensions between them during pivotal moments of the space race. Numerous instances illustrate this function of space diplomacy such as the Dryden-Blagonravov agreement (1962), and the Apollo-Soyuz Test Project (1975). In the post-Cold War period, the Shuttle/MIR missions (1994–1998) and the creation of the International Space Station (ISS) in 1998 are two notable instances where space diplomacy played a significant role in reducing tension between the two former adversaries and in fostering positive engagement through the use of space as a foundation for this new geopolitical relationship.

Presently, there are a plethora of examples that demonstrate the efficacy of space diplomacy in mitigating tensions among actors. In the context of an international system marked by escalating geopolitical tensions and disputes, there has been a notable increase in the number of space agreements across various formats, including multilateral (Artemis Accords, ILRSCO), regional (ESA, APSCO, ALCE), and bilateral. This phenomenon stands as a rare example of countries demonstrating a willingness to collaborate, highlighting a potential area of cooperation in the face of rising international tensions. Notably, several instances underscore the pivotal role of space diplomacy in mitigating tensions among spacefaring nations. These include the following: (1) the ongoing exchange of data between China and the United States in the context of the Indian mission Chandrayaan 3, despite the Wolf Amendment (2011), which prohibits NASA from cooperating with the Chinese government, and the prevailing global economic, technological, and geopolitical competition; (2) the ongoing cooperation between the United States and Russia on the ISS, despite the conflict in Ukraine. The Expedition 71 mission to the International Space Station (ISS), which took place between April and September 2024, shortly after the invasion of Ukraine, comprised four astronauts and three cosmonauts. Similarly, Expeditions 72 and 73, which occurred in 2024 and 2025, respectively, also featured participants from the United States, Russia, Japan, and Europe.

Consolidate Long-Term and Stable Geopolitical Partnerships

Another strategic role that space diplomacy can effectively play in the international system is to build long-term partnerships with traditional allies. While the international system is inherently dynamic, states value long-term partnerships. Given the strategic importance of outer space and its significant geopolitical value for international actors, the use of space diplomacy for cooperation in space can reinforce traditional partnerships, provide stability to existing alliances, and facilitate the pursuit of new long-term agreements.

An excellent illustration of this space diplomacy usage is provided by the long-term collaboration between ESA and NASA. Since its foundation in

1975, ESA has fostered a robust partnership with NASA, collaborating on a number of high-profile space projects and missions. These include the Cassini-Huygens mission (1997–2017), the James Webb Telescope (1996–present), and the International Space Station (ISS) (1998–present), Artemis program (2020–present) among others (Kiraly 2024). The collaboration on these strategic and sensitive global agenda items has reinforced the historical transatlantic relationship between the United States and Europe.

The formation of new space multilateral agreements, such as the Artemis Accords signed in October 2020 and the Russian-Chinese agreement to establish the International Lunar Research Station signed in March 2021, appears to be evidence of how space diplomacy has been utilized to foster long-term space partnerships that mirror the geopolitical alliances that have emerged in the international system over the past decade. Some scholars have referred to these as “space blocs” (Ben-Itzhak 2022). While both space alliances are open to new members, the current processes are focused on establishing long-term geopolitical partnerships. The United States is strengthening existing relationships with traditional allies such as Canada, Japan, South Korea, and Italy. Concurrently, China is integrating traditional partners like Iran, Serbia, Pakistan, and Turkey into the new space alliance.

Similarly, countries involved in the BRICS process are employing space diplomacy as a means of strengthening this association. In May 2022, the BRICS established a new Joint Committee on Space Cooperation with the involvement of the five national space agencies from the five member countries. The objective of this committee is to facilitate the sharing of remote sensing satellite data from six operating satellites (Park 2022).

Build Norms and International Regimes

Despite the absence of a supreme authority or global government in the international system, nation-states maintain that global cooperation is feasible through negotiation, bilateral and multilateral agreements, and the establishment of norms and regimes. In the domain of outer space, states engage in active diplomacy to establish norms and regimes that enable them to regulate behaviors. The objective is to delineate boundaries that will prevent potential misbehavior by actors in outer space. Space diplomacy represents a fundamental instrument utilized by states to cultivate ties with other entities and establish norms and international regimes. In the context of space, this is manifested in the form of an international set of norms that govern outer space policy.

Since the launch of Sputnik 1 in October 1957, there has been a notable increase in diplomatic activity related to the establishment of an international framework for space activities. These efforts include the Outer Space Treaty (OST), which entered into force in October 1967. The OST is the main legal instrument that codifies the principles of international law of space activities. It was signed by the two major space powers at that time, the United States and the Soviet Union, and then, four additional space regulatory instruments were established to address more specific matters related to outer space. Subsequently,

a series of declarations of principles have been issued with the objective of regulating specific domains, including radio and television broadcasting, remote sensing, nuclear energy sources in space, and international cooperation in the field of space (Nucera 2019).

While these agreements have demonstrated certain limitations, there is a consensus among experts regarding the relevance of the body of law governing space-related activities. This body of law, which includes a variety of international agreements, treaties, conventions, and UN resolutions, serves as a foundation for an international space regime and an effective tool for international cooperation. The majority of experts concur that the Outer Space Treaty has been instrumental in preventing the proliferation of nuclear weapons and the militarization of outer space. At present, the two principal global space initiatives, the Artemis Accords and ILRSCO, in conjunction with all space regional processes, acknowledge the Outer Space Treaty as the fundamental pillar for future negotiation about the global governance of outer space.

Although no new multilateral or bilateral space agreements have been signed in recent decades, it is evident that space diplomacy has contributed to the establishment of several channels of discussion among major stakeholders. In various contexts and arenas of action, stakeholders have engaged in discussions concerning the articulation of diverse interests to establish an international regime that enables peaceful governance of outer space. A notable example is the Treaty on Prevention of the Placement of Weapons in Outer Space (PPWT), a proposed treaty aimed at preventing any nation from placing weapons in orbit. In 2008, the European Union introduced a separate proposal for a non-binding International Code of Conduct for Outer Space Activities. This Code has undergone numerous revisions during extensive multilateral consultations involving over 100 countries. In 2013, the United Nations Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities developed a guideline based on recommendations from a group of experts from various states. In 2016, COPUOS developed a “Guideline for the Long-Term Sustainability—LTS—of Outer Space Activities.” The development of these guidelines was informed by the insights of four groups of experts, each nominated by a state and an intergovernmental organization with permanent status at COPUOS. In 2019, the final Guideline for Long-Term Sustainability was adopted by COPUOS.

The articulation of these proposals has necessitated extensive negotiations and diplomatic efforts, aimed at aligning diverse interests. The present guidelines aim to establish a novel and comprehensive framework, underpinned by the consensus of space-related actors.

Promote Institutionalization

Concurrently with the establishment of norms and regulatory frameworks by states, major space powers are seeking the creation of common intergovernmental and multilateral institutions as a forum for discussion and negotiation. The concept of institutionalized cooperation, inspired by a liberal approach,

underscores the role that institutions, organizations, forums, and multilateral actions play in maintaining peace on Earth. Such institutions may be established with a general purpose or may be created to address specific goals.

Space is a valuable instrument for enhancing and strengthening connections between international entities, particularly in the context of scientific collaboration. The advent of space diplomacy has led to the emergence of a robust mechanism for fostering scientific cooperation and the establishment of novel institutional frameworks. Common institutions at the international level constitute a distinctive forum for discussion, negotiation, and agreement, wherein international actors may pursue their respective interests while simultaneously attempting to articulate them within a broader context of shared objectives.

The formation of international institutions in the space domain has a long tradition. In the wake of the 1957 launch of Sputnik 1, the United Nations established the Committee on the Peaceful Uses of Outer Space (COPUOS). This body was given the overarching responsibility to address issues about upper atmospheric science. The United Nations Office for Outer Space Affairs (UNOOSA) serves as the secretariat for the COPUOS and is tasked with ensuring the smooth functioning and record-keeping of the Committee on a daily basis. Currently, both entities play a pivotal role in fostering international collaboration between state members and strengthening inter-agency cooperation in the field of space exploration.

The process of institutionalization has undergone significant developments over the past few decades, resulting in the emergence of both informal and formal institutions at various levels of action. This encompasses regional institutions such as the ESA, APSCO, and AfSA, as well as international organizations, including the announcement by China on April 24, 2024, of the establishment of the International Lunar Research Station Cooperation Organization (ILRSCO) (Jones 2023). Despite the absence of any indication from the Artemis Accords that they intend to institutionalize the global alliance, the proposal to establish a framework for collaborative nations may necessitate a further process of institutionalization in the near future.

Enhance the Regionalization of Space

Space diplomacy is also playing an instrumental role in the growing trend of regionalization in the global marketplace. Since the end of the Cold War, we have observed an increase in the number of states that have chosen to form voluntary associations and consolidate resources in order to create shared functional and institutional arrangements with other states that are geographically proximate. In essence, these actors also engage in a growing network of economic, cultural, scientific, diplomatic, political, and military interactions (Kacowicz 1998).

The regionalization process has had a remarkable impact on the space sector, with significant developments taking place. In essence, the majority of regional integration processes are engaged in cooperative efforts within the space sector. The European Space Agency (ESA), established in 1975, was the

first and most prominent regional international organization for space activities, and it serves as an organizational model for scientific, technological, and political cooperation in space at the regional level (Nucera 2019). The original 10 founding members were joined by another 12, resulting in the current 22 members. These members maintain their own national space agencies while leveraging the ESA as a platform for regional collaboration.

The conclusion of the Cold War paved the way for increased regional collaboration in space. Building on the ESA model, new regional processes were subsequently established to further enhance space cooperation. In essence, the majority of regional integration processes are engaged in the space sector, utilizing space as a novel instrument or mechanism of space diplomacy. This model has been further developed through the establishment of formal institutions and the establishment of norms. In the post-Cold War era, the inaugural instance of this phenomenon was the establishment of the Asia Pacific Regional Space Agency Forum (APRSAP) in 1993. This initiative, spearheaded by Japan, encompassed over 50 states. The process of space regionalization has intensified with the formation of five new space blocs in the last two decades. These include the Asia-Pacific Regional Space Agency Forum (1993), the Asia-Pacific Space Cooperation Organization (2005), the Arab Space Cooperation Group (2019), the Latin-American and Caribbean Space Agency (2021), and the African Space Agency under the African Union (2023) (Del Canto Viterale 2024).

Address Global Challenges

As previously discussed by several experts (Fedoroff 2009) and specialized organizations (UNESCO 2010), scientific collaboration can be utilized as a platform for international development. Science has demonstrated its potential as a valuable tool for addressing a range of global challenges that require effective and truly international cooperation.

The international agenda has undergone significant transformation in recent decades, collectively shaping an increasingly open, extensive, and complex international agenda. This agenda encompasses global challenges related to education, poverty, health, economic growth, energy, and the environment. These challenges necessitate the collective engagement and collaboration of all stakeholders within the international system. Scientific collaboration has played a pivotal role in addressing global challenges, including those in health (e.g., the response to the pandemic caused by the novel coronavirus), the environment (e.g., the Paris Agreement on climate change), and energy (e.g., the International Energy Agency's efforts).

A considerable proportion of space activities have historically been dedicated to addressing some of the most pressing issues on the global agenda, including natural disasters, poverty, economic development, and education. A considerable portion of the resources of numerous national space programs, including those of India, Brazil, and Japan, have been allocated to the social benefits of space activities, such as communication, meteorology, and

transportation. This demonstrates the long-standing significance of space in facilitating enhanced and expedited communication via the Internet and GPS, as well as in mitigating the impact of natural disasters and supporting agricultural practices.

The utilization of space diplomacy to address global challenges has increased in recent years, largely attributable to the active involvement of intergovernmental space organizations, such as the United Nations Office for Outer Space Affairs (UNOOSA). This has resulted in the establishment of the SPACE4SDGS program, which utilizes space technology to advance the 2030 Agenda for Sustainable Development. The Agenda encompasses 17 Sustainable Development Goals (SDGs) and 169 associated specific targets (UNOOSA 2024). Furthermore, UNOOSA is engaged in a collaborative effort with ESA to create a comprehensive Space Solutions Compendium. This document is intended to serve as a comprehensive repository of information regarding space-based resources, applications, and tools that can facilitate the monitoring or attainment of the Sustainable Development Goals.

Promote Cooperation with the Global South

Space diplomacy has been utilized to foster collaboration with developing countries in the Global South, facilitate technology transfer, and promote economic development in these nations. Concurrently, space-faring nations have also utilized space diplomacy as a geopolitical instrument to gain influence in developing countries that often possess more modest space programs. From a strategic perspective, certain space powers have strategically employed space cooperation as a means of fostering closer ties with middle and small powers. These cooperative endeavors have also helped these countries develop their own national space programs.

Presently, space powers are offering satellite development and launch services to developing countries that lack a notable presence in space. China is leveraging space diplomacy to extend its reach in regions such as Africa and Latin America, providing expertise and resources to these countries to enable the launch of their own national space programs. China has built and launched satellites for Nigeria (2007, 2011), Algeria (2017), Sudan (2019), and Ethiopia (2019). Additionally, China and African countries are constructing remote sensing satellite networks to support the logistical integration of the Belt and Road Initiative (BRI) partner states. Concurrently, the United States is endeavoring to persuade developing countries to accede to the Artemis Accords, offering incentives for the collective exploration of outer space. To date, the United States has successfully engaged countries from various regions, including Latin America (Colombia, Peru, Dominican Republic), Africa (Angola, Rwanda), Eastern Europe (Poland, Ukraine, Bulgaria), the Middle East (UAE, Saudi Arabia, Bahrain), and Southeast Asia (Thailand).

At the international level, the United Nations has launched multiple initiatives aimed at fostering more sustainable and inclusive growth in space-related activities. These initiatives seek to establish collaborative frameworks with

countries in the Global South, facilitating the development of novel space technologies and ensuring that the benefits derived from space utilization are equitably distributed. Despite the present contributions of the space sector to society, UNOOSA has advocated for a more extensive implementation of space-related activities to support the 17 Sustainable Development Goals (Space4SDG – United Nations). Another relevant initiative is the new Space2030 Agenda, proposed in 2018 by the Outer Space Committee and aimed at reinforcing international cooperation for the peaceful uses of outer space and social applications. Among the primary objectives of this initiative is the strategic enhancement of the space sector's role as a pivotal catalyst for sustainable development to further the societal benefits derived from space-related endeavors. The overarching objective of the Space2030 Agenda is to ensure that all nations have access to and can benefit socioeconomically from space science, technology, and information.

5 CONCLUSION

This chapter explores the role of space diplomacy in facilitating international cooperation within the context of a new international, technological, and space age.

Space diplomacy is conceptualized as a specific variety of science diplomacy. Within the domain of science diplomacy, space diplomacy signifies a distinct approach that utilizes issues pertaining to outer space to cultivate positive relationships among actors engaged in addressing common problems.

The central research question of this chapter seeks to understand how space diplomacy, as a form of science diplomacy, helps address the challenges of a rapidly changing global order. The primary hypothesis of this chapter is that space diplomacy will play a pivotal role in the twenty-first-century international system by reducing geopolitical tensions and fostering trusted relationships among states. This general hypothesis is corroborated by a range of evidence that demonstrates space diplomacy's relevance and utility as a tool for international cooperation.

Space diplomacy is not a novel phenomenon; it played a substantial role in the twentieth-century international system, reducing tension among the two superpowers and creating various mechanisms of cooperation at the international level. These include space regimes (OST), international institutions (COPUOS), regional agencies (ESA), and international joint missions (Apollo/Soyuz Test Project) among others.

Despite the tradition of using space diplomacy in the twentieth century, the chapter has delineated a novel international, technological, and space context in which space diplomacy has become an even more pivotal instrument of international cooperation. The international system has undergone a profound and systemic transformation, with significant shifts in economic, geopolitical, and technological parameters, giving rise to a new configuration of a more complex and multipolar global system. Concurrently, the analysis has revealed

the emergence of new actors, interactions, processes, trends, and a space agenda that are transforming the space domain of the twenty-first century.

In light of the emergence of a multipolar international system in recent years, marked by escalating geopolitical tensions among major powers, the role of space diplomacy has arguably become more significant than ever before.

A review of historical and contemporary evidence indicates that space diplomacy plays a crucial role as a mechanism for international cooperation. In this sense, space diplomacy can be considered a useful diplomatic instrument for the following purposes: (1) the reduction of tension and the development of positive engagement; (2) the consolidation of long-term and stable geopolitical partnerships; (3) the construction of norms and international regimes; (4) the promotion of institutionalization; (5) the enhancement of the regionalization of space; (6) the addressing of global challenges; and (7) the promotion cooperation with the Global South.

The increasing complexity of the international system, the growing geopolitical tension in the twenty-first century, the unprecedented technological revolution, and the renewed interest of most international actors in outer space have positioned science diplomacy as a formidable tool for fostering positive relationships between actors engaged in addressing common problems, such as those pertaining to outer space, and for facilitating commitments for international cooperation. Therefore, further research should be a priority.

Acknowledgments The author acknowledges the Department of Space Studies, John D. Odegard School of Aerospace Sciences at the University of North Dakota for supporting this research project.

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Biological Weapons and Science-Based Policymaking

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1 REGULATING BIOLOGY UNDER THE BIOLOGICAL WEAPONS CONVENTION

Emerging biotechnologies offer transformative benefits for society, while also introducing new and evolving security risks for the intentional spread of disease. These risks are amplified by the convergence of the life sciences with other emerging technologies, most notably artificial intelligence, which could accelerate research processes, overcome existing barriers to misuse, and change perceptions around the use and feasibility of biological weapons (Ghionis 2024). AI tools could also raise the ceiling of harm in a variety of ways, for example, the use of large language models to suggest candidate biological agents, or AI-enabled biological tools to design pathogens with more infectious properties (Rose and Nelson 2023). Traditional biosecurity approaches have relied on physically restricting access to equipment and select agents, such as The Australia Group's focus on regulating exports of chemicals, biological agents, and equipment; however, advances in technology may allow malicious actors to circumvent these barriers (The Australia Group 2023). Together, these emerging technologies are not merely increasing biological risk, but reshaping how such risk emerges, spreads, and can be governed.

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There are no comprehensive international frameworks to govern biological risks, with governance instead relying on multiple overlapping treaties, organizations, export controls, and national regulations (Patrick and Barton 2024). The 1972 Biological Weapons Convention (BWC) is one major achievement in global biological disarmament as the treaty prohibits the development, production, stockpiling, and use of biological and toxin weapons, and now has nearly universal coverage with 189 States Parties (United Nations Office for Disarmament Affairs 2026). The BWC was notable as the first multilateral treaty to prohibit an entire class of weapons of mass destruction and entered into force in 1975 after a long period of diplomacy and negotiations (Andersen and Balmer 2025). Although its primary purpose is to uphold the norm against biological weapons, it has also become a forum to discuss the management of dual-use research and capacity-building for biosafety.

While often regarded as a success for maintaining the norm against biological weapons, the BWC remains constrained by persistent issues of institutional support, funding arrangements, political will, and technical capacity. It lacks a continuous international agency and long-term staff to support the Convention, and instead relies on an Implementation Support Unit (ISU), which must be renewed every five years at the BWC Review Conferences. The ISU has just four full-time staff members and an annual budget of around €1.35 million, compared to the Chemical Weapons Convention (CWC), which has the institutional support of the Organisation for the Prohibition of Chemical Weapons with approximately 500 staff members and an annual budget of €87.6 million (UN 2022, OPCW 2024). The BWC also has no verification mechanism to ensure compliance with the treaty; a complex problem, as it is difficult to distinguish offensive biological research from defensive research without invasive inspections. This is a notable difference to the CWC, which has a strong verification regime and about 5000 inspections of industrial facilities so far (OPCW 2026). There is evidence that multiple States Parties continued to conduct offensive biological research even after signing the BWC, which underscores the importance of integrating some form of compliance into the Convention (Frischknecht 2003). Finally, the BWC currently has no systematic mechanism to stay up-to-date with advances in technology and how they might change the biological weapons landscape. Discussions to implement a systematic review process have been ongoing for decades without reaching consensus on issues such as the structure of working groups and funding arrangements (BWC 2023b). Together, these limitations raise fundamental questions about whether the BWC, in its current form, can remain effective amid accelerating scientific change and mounting geopolitical strain.

2 VIEWING THE BWC THROUGH THE LENS OF SCIENCE DIPLOMACY FRAMEWORKS

The BWC is a clear example of a multilateral forum where science diplomacy (SD) takes place, that is, where science and diplomacy are both closely intertwined. As such, it helps highlight how the initial Royal Society and American

Association for the Advancement of Science (RS-AAAS 2010) and the subsequent Gluckman et al. (2017) SD frameworks may apply to it. The tripartite SD taxonomy developed by the RS-AAAS report of 2010 considers how scientific advice may inform foreign policy objectives—*science in diplomacy*, how diplomacy can help facilitate international science cooperation—*diplomacy for science*, and how science cooperation can improve international relations between countries—*science for diplomacy*. This framework encompasses a variety of actors, is fairly broad, and has been criticised for taking an overly positive lens (e.g. Rungius and Flink 2020). A subsequent framework (Gluckman et al. 2017) focuses exclusively on the actions of states, which seek to ‘*advance [their] national needs*’, to ‘*address cross-border interests*’, and to ‘*meet global needs and challenges*’ using science diplomacy.

The inception of the BWC itself and its diplomatic process aiming at regulating science and some of its applications and uses could be considered as *diplomacy for science* (DfS) by successfully bringing nations to negotiation around a global challenge of scientific nature. However, here diplomacy is not used to *help* science or scientists (in the traditional sense of the positive preposition ‘*for*’ and its aim of ‘*facilitating international science cooperation*’) but to *limit* its use toward national interests (for military use). Hence, it does not exactly fit the DfS definition of the RS-AAAS 2010 report, unless this scientific cooperation is understood to be toward limiting certain uses or helping with monitoring, for example. The state-led approach and collective will to address the issue of development and disarmament affairs—despite disagreements on its implementation and varied degrees of support—is well captured by the Gluckman et al. (2017) framework as an example of actions taken by states to ‘*meet global needs and challenges*’. However, the science at stake here is closely intertwined with ‘hard power’, and the duality between collaboration and competition (Ruffini 2020) is thus exacerbated. Therefore, the actions of states that serve to ‘*advance [their] national needs*’ may be concurrently at odds with the ones that would allow them to ‘*meet global needs and challenges*’, which is not well captured by the wording of the taxonomy, even if this tension is noted by the authors. Similarly, the dimension of ‘*science in diplomacy*’ (science advice informing foreign policy) may also look very different if considered as science informing national objectives versus science informing global policy, as those may also directly oppose one another. Finally, if we consider ‘*science for diplomacy*’ (SfD, the science cooperation that can help international relations), it is clear that it may not be in the interest of a state actor to act along this dimension if it is not aligned with its foreign policy objectives, and science cooperation may therefore be prevented or hindered instead. These two points are exemplified by the longstanding and deadlocked discussions on the implementation of a systematic S&T review process due to political disagreements, which we explore in more depth in the next section.

The aforementioned issues show how the SD frameworks are not necessarily easy to apply in certain contexts and quickly find their limits when dual-use, security-sensitive, and heavily contested technologies are considered, which

makes cases such as the BWC ideal testbeds to scrutinize them (Rüffin and Rüländ 2022). It is worthwhile to note that in 2025, a report from the European Commission introduced a fourth dimension to the original framework of 2010, namely, ‘*diplomacy in science*’ (EC 2025), and that the RS-AAAS simplified theirs by considering only two dimensions: ‘*diplomacy impacting science*’ and ‘*science impacting diplomacy*’ (RS-AAAS 2025). It is, however, beyond the scope of this case study to address these new or reframed dimensions.

3 CAN THE BWC STAY RELEVANT IN A CHANGING SCIENCE AND TECHNOLOGY LANDSCAPE? A DEEPER DIVE INTO THE ‘SCIENCE IN DIPLOMACY’ DIMENSION

Continuous advances in research and innovation are redefining the context within which the BWC operates. The definition of biological weapons in the Convention is intentionally future-proofed, as the ‘general purpose criterion’ ensures that agents are considered weapons based on malign intent, rather than through lists of specific organisms or technologies which would quickly become outdated (Andersen and Balmer 2025). This allows the Convention to have continuing relevance regardless of how the research landscape changes.

However, a clear understanding of how developments may affect the Convention is essential for national implementation to be effectively carried out. The current process consists of a brief five-yearly review of developments in science and technology, and despite wide recognition that a more frequent and systematic process is necessary, it has been difficult to institutionalise a formal scientific advice mechanism. Discussions at BWC meetings have struggled to reach consensus on issues related to the structure and composition of the S&T committee body, as well as funding arrangements to support the expert meetings (Guthrie 2026). Many delegates have mentioned the importance of ‘independent’ experts who are not influenced by politics (Revill et al. 2021). These issues with the S&T review mechanism illustrate the difficulty for the dimension of ‘*science in diplomacy*’ (SiD) that would ‘*ensure the effective uptake of high-quality scientific advice by [international] policymakers*’ (RS-AAAS 2010), a crucial aspect highlighted in the report. As briefly mentioned above, the taxonomy fails to address that scientific advice may mostly be used to serve national foreign policy goals, and that only certain scientific information and evidence is allowed to be presented or used in many multilateral fora. Strategic information manipulation and political interference can also further undermine processes and discussions. For example, a mixed-methods study of the Ninth Review Conference of BWC found that Russian disinformation diverted attention from technical discussions, consuming significant negotiating time, and contributed to a weakened final document (Sundelson et al. 2025). Many multilateral fora and organizations lack proper science advice mechanisms, which would enable a more objective flow of information (noting the IPCC and IPBES mechanisms as two notable counterexamples, despite their known flaws). Implemented properly, a BWC

science advice mechanism could help policy to keep pace with biotechnology developments, improve consensus on issues such as verification, and involve a wider range of experts, including fields such as foresight and international law (Rojas et al. 2024).

Many states have emphasised that the S&T review process should also draw out opportunities, as Article X of the Convention focuses on international cooperation for peaceful uses of biological sciences, encouraging states to participate in *science for diplomacy* (Chair of the Non-Aligned Movement 2025). Related to Article X, there have been a variety of transnational initiatives and networks set up for biosafety and biosecurity capacity-building. Yet, as exemplified by the joint statement by the Non-Aligned Movement, certain states raised grievances after COVID-19 that the Article X obligation had not been fulfilled, with vaccine and healthcare inequalities during the pandemic (BWC 2022b). The Assistance and Cooperation Database to facilitate Article X has been generally underused, although there was a peak of offers and requests in 2024 (The United Nations Office at Geneva 2017). There are currently efforts ongoing at the 2026 Working Group to develop a formal mechanism for international cooperation and assistance, but finding consensus on the composition of the body, administrative issues, and funding arrangements remains onerous (Guthrie 2025). With renewed efforts in this area and more focus on building trust, the BWC could become more of a diplomatic tool to balance national security interests with global biosafety.

4 AN OPPORTUNITY TO STRENGTHEN SCIENCE DIPLOMACY

There is currently renewed political interest in developing a compliance and verification protocol, as formal discussions on this issue have recently restarted after a period of stagnation. The last discussions to develop a legally binding verification protocol took place between 1995 and 2001, with negotiations abruptly collapsing at a late stage in the process (Chevrier 1995; Kervers 2002). The issue was not formally revisited until the Ninth Review Conference in 2022, where States Parties agreed to hold an intersessional programme with meetings on measures to improve compliance, verification, confidence-building, and transparency (BWC 2022a, 2023a). Since the negotiations in 2001, significant advances in science and technology have created new opportunities and challenges for the development of a verification regime (Revill et al. 2022). This could offer new technological possibilities to verify that states are not engaging in offensive biological research; a point highlighted at the 2025 United Nations General Assembly, where President Trump announced that the United States will lead an international effort to explore the development of an AI-enabled verification system (OECD 2025). Such statements signal a renewed political interest in technological solutions to the longstanding challenge of verification under the BWC.

Emerging technologies could offer other opportunities to strengthen compliance, for example, AI could help in the analysis of big data to detect illicit

activities, as suggested for nuclear and chemical arms control (Borrett et al. 2020; Arterburn et al. 2021). Satellite imagery and publicly available information could support this, such as the open-source Global BioLabs project set up by civil society to track maximum containment labs globally (Jeremias and Himmel 2016; Global BioLabs 2023). Remote sensing technologies and site sampling could also help to surveil high-containment labs, although the implementation of this would be politically complicated (Millett et al. 2022).

Unfortunately, as it stands now, science has not yet been able to help diplomacy in a sustained or institutionalised way, and SfD has not materialized at the level of outcomes, likely due to the political roadblocks and national interests that obstruct this pathway, particularly as the consensus-based decision-making rule at the BWC means that a decision is blocked if a single state disagrees. Where science diplomacy deployed by state actors fails to address global challenges due to overriding national interests, and when competition takes over collaboration, leading to gridlock (Hale and Held 2018), the solution may lie beyond the state-centric system. Indeed, international organizations and civil society have played, and continue to play, a crucial role in pushing for stronger international norms and presenting solutions where progress is stagnating. The increasing rise and influence of non-state actors has been noted by various recent reports (RS-AAAS 2025, EC 2025). While their capacity to directly influence negotiations at the BWC is limited (and more recently they have even been restricted from the long-running tradition of presenting statements during the general debate), they can still advocate for technologically enhanced verification mechanisms, initiate research and dialogue, or contribute to science advice that is not driven by national interests. For example, civil society can bring much-needed energy and innovative ideas to the BWC and present their work at side events, such as the Nuclear Threat Initiative's recent work on enhancing transparency to reduce risks of misperception and misuse (Nuclear Threat Initiative 2024).

While it is necessary to be mindful of not falling into a 'solutionistic narrative' (Rungius and Flink 2020) and to acknowledge that the role of non-state actors can be limited, or even instrumentalized, by the political realm, it is nonetheless important for the scientific community at large to continue to put pressure on state actors (Grönvall 2005; Saric et al. 2025). In the context of the BWC, individual scientists in the United Kingdom and United States were instrumental in persuading their governments to put biological disarmament onto the international agenda in the 1960s (Guillemin et al. 2016). It is clear that scientists, regardless of their state, have crucial knowledge of developments in life science and could play a critical role in assessing the potential risk of weaponizing scientific breakthroughs (Veerakumarasivam et al. 2023; Shang et al. 2023). Recent scholarship emphasises this growing role of transnational networks of scientists, and how they contribute their expertise outside formal plenaries, suggesting that BWC governance is increasingly operating through parallel and multi-track channels (Bao et al. 2025; Namdeo and Zhang 2024).

5 CONCLUSION

The RS-AAAS 2010 framework does not distinguish between state and non-state actors, leading to a lack of clarity between the various actors of science diplomacy and their often-competing objectives. While the Gluckman et al. (2017) framework illustrates the state actors' objectives (and helps highlight the less 'positive' side of SD), it is now time to pay closer attention to non-state actors (Gluckman 2022) and how they can play a greater role in '*science for diplomacy*' and '*science in diplomacy*', through a '*diplomacy for science*' that is a vehicle to advocate for science (and not for foreign policy advancing national interests, as a state actor would). This is precisely what actors such as the International Science Council (ISC), AAAS, The World Academy of Sciences, the Geneva Science Diplomacy Anticipator and many others are aiming to do. For example, the ISC recently put in place a group of experts with the aim to help design a science advice mechanism, characterise potential compliance and verification measures, and identify how to best drive international cooperation and assistance (International Science Council 2024), bringing their inputs to the fifth session of the Working Group on the Strengthening of the Biological Weapons Convention. The InterAcademy Partnership has also played a key role in developing ideas for a scientific advisory body (IAP 2023). Overall, more attention should be paid to these actors and their increasing role in science diplomacy. After all, it is important to bear in mind that, even in the highly contested realm of nuclear weapons, groups of experts such as the 'Pugwash Conferences' have been informally credited with having led to many important conventions and treaties (Kraft and Sachse 2019), as epitomized by their Nobel Peace Prize in 1995.

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Disaster Resilience Technology and Diplomacy: Japan and the Asia-Pacific

Sumie Nakaya 

1 JAPAN'S LEADERSHIP IN DISASTER-PRONE ASIA

Japan has been a leader in disaster resilience diplomacy since it spearheaded the International Decade for Natural Disaster Reduction in the 1990s. Since then, the country has hosted the World Conference on Natural Disaster Reduction three times, each time fostering a shared vision to combat the devastating impacts of disasters (Schemper 2019). Japan also promotes responsible technology development by launching the Hiroshima AI Process during its G7 presidency in 2023 to establish shared guiding principles, a code of conduct, and a reporting framework (Callegari and Alaamer 2025).

This new posture of science diplomacy offers salvation in Asia, the world's most disaster-prone region. Nearly 80% of displacement caused by natural disasters occurs in Asia (United Nations Office for Disaster Risk Reduction 2022). Rapid urbanization compounds the region's disaster vulnerability, home to 21 of the world's 35 megacities with over 10 million populations, overwhelming public services, and infrastructure capacities. Technology to overcome these physical and socioeconomic barriers is crucial for lifesaving.

2 TECHNOLOGICAL INNOVATIONS FOR DISASTER RESILIENCE

Digital tools have revolutionized disaster risk management (Dikmener et al. 2023). Signs of calamities are monitored through the Internet of Things, including seismic, heat, weather, radiation, and flood sensors installed on

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buildings, roads, grids, and other devices connected to information and communication technology (ICT) (Samarakkody et al. 2023; Khan et al. 2023). These big data are exchanged, analyzed, and stored through cloud technology and AI automation, machine and deep learning, natural language processing, and text, image, and audio generation to increase the speed and accuracy of disaster forecasting, response, and recovery (Yigitcanlar et al. 2020; Abid et al. 2021). AI-enhanced social media are the source of crisis detection, damage assessment, and emergency communication (Imran et al. 2020; Bengtsson et al. 2011). Virtual reality is a powerful tool for conveying disaster risks and raising public awareness and preparedness.

Remote sensing and geographical information systems provide critical location data for all phases of disaster management (Kurwakumire et al. 2019; Cariolet et al. 2019). Geodata crowdsourcing and unmanned aerial vehicles expand disaster assessment and guide rescue operations, especially in inaccessible areas (Bennett 2010; Tzavella et al. 2024; Meier 2012). Disaster relief technologies also include 3D printing, which produces low-cost shelters for disaster victims, and blockchain technology, which ensures safe, secure, and cost-effective aid distribution.

3 JAPAN'S SCIENCE DIPLOMACY INITIATIVES

Asia lacks robust regional cooperation frameworks due partly to historical divisions on the Korean Peninsula and between China and Taiwan. In this neighborhood rife with unresolved tensions, Japan's science diplomacy has focused on technical assistance and rulemaking on common goals, such as space cooperation. This non-intrusive approach has fostered dialogue and confidence-building, but political mistrust remains deep.

Remote Sensing

Japan led the establishment of the Asia-Pacific Regional Space Agency Forum (APRSAF) in 1993 and its dedicated capacity for disaster response, Sentinel Asia, in 2006. The Ministry of Education, Culture, Sports, Science, and Technology of Japan and the Japan Aerospace Exploration Agency (JAXA) convene APRSAF's annual meetings that unite public, private, and academic institutions involved in space exploration throughout Asia. JAXA also manages Sentinel Asia with the Asian Disaster Reduction Center (established in Kobe following the first World Conference on Disaster Reduction in 1998). When a disaster strikes, JAXA delivers satellite imagery captured by Advanced Land Observation Satellites and an automated damage analysis within two hours of observation.

These Japanese contributions have forged partnerships that would not exist otherwise: Taiwan has answered Chinese emergency observation requests, as in the Xinjiang earthquake of January 2024, and Indian satellites have helped

Pakistan assess flood and landslide impacts.¹ An industry expert attests that APRSAF's inclusivity and clear standard-setting have enabled Sentinel Asia to galvanize mutual peer support in times of crisis.² Science diplomacy can thus transcend political divides for humanitarian imperatives, with Japan serving as a technical secretariat to facilitate the process.

Predictive Data Analytics

Japan's science diplomacy also extends to disaster forecasting assistance, which combines earth observation and big data analytics. For example, the flood risk analysis through the Data and Integration and Analysis System (DIAS), the primary platform for storing and publishing datasets in Japan, blends sensor and satellite data monitoring and processing, water flow modeling, and reservoir simulation (Kawasaki et al. 2018; Rasmy et al. 2023). Japanese aid brought this methodology to build near real-time flood simulations with limited in-situ observation in Myanmar and Sri Lanka (Meguro and Honma 2020; Yabe et al. 2014). In these conflict-affected countries, Japan's disaster resilience diplomacy has provided an entry point to continue engaging public administration and sustained local science education and research amid political disruption and international isolation (The Ministry of Foreign Affairs of Japan 2020).

Similarly, Official Development Assistance delivered through the Japan International Cooperation Agency (JICA) has transferred the earthquake analysis system developed by Japan's National Research Institute for Earth Science and Disaster Prevention to Indonesia, the Philippines, and Turkey. In the Philippines, JICA established immediate seismic and volcanic observation with GPS and drone monitoring and a public data portal, which enabled resident evacuation during a volcanic eruption in January 2020 (Minter 2020).

4 CHALLENGES AND OPPORTUNITIES

Crisis Communication

Compared to Japan's excellence in disaster detection and simulation technologies, emergency response mechanisms, including crisis communication, remain conventional (Utani et al. 2011). When the magnitude 9.0 earthquake hit eastern Japan in March 2011, social media was still in its infancy, and citizen-led crisis mapping was limited to a small group of Japanese scientists monitoring radiation from the damaged nuclear plants in Fukushima (Utani et al. 2011; Hayakawa et al. 2014). Since then, major online platforms, such as Google, Yahoo, and LINE, have started issuing emergency notifications (Ishiwatari

¹Use cases are found on the Sentinel Asia homepage (<https://sentinel-asia.org/EO/EmergencyObservation.html>).

²An interview with a Japanese member of APRSE, Tokyo, 9 December 2024.

2024). However, only a few lifesaving rescues have been made based on digital reporting (Sekiya 2017; Song and Fujishiro 2019; Utsu and Uchida 2020; Yabe et al. 2019). This prompted a risk management startup, Spectee, to create a system in 2020 that combines AI-driven social media analysis with meteorological data, remote sensing, and government alerts for real-time crisis communication. In 2025, JICA adopted this system as part of ODA to the Philippines (Casucian 2025).

Crisis communication is about learning the needs and priorities of affected communities and making informed decisions, as much as it is about public messaging (Yabe et al. 2022). While Japan's disaster resilience focuses on observing, detecting, and simulating nature's physical conditions, South Korea and Taiwan emphasize the social systems of managing disasters (Inoue 2015). The Japanese government also established an inter-agency Shared Information Platform for Disaster Management (SIP4D) in 2014 to link data and disaster management. Nevertheless, the 2019 Typhoon Hagibis caused 86 deaths despite DIAS's 32-hour-advance flood prediction, which suggests a fundamental breakdown between forecasting and response technologies (Ma et al. 2021). Japan would benefit from cross-learning with neighboring countries and international actors specialized in emergency assistance, such as the UN Office for the Coordination of Humanitarian Affairs, to fill this gap.

3D Technologies and Blockchain

Blockchain and 3D technologies can also be better utilized for disaster response in Asia. Blockchain developments in the region have primarily been in the financial and energy sectors, led by Singapore. Meanwhile, international relief organizations increasingly find blockchain effective and safe for aid delivery. Japan launched its first blockchain aid project to track child labor in West Africa in 2021 (Asian Development Bank 2022; United Nations 2020).

Japan's 3D printing of temporary shelters also began only in 2023, delayed by its stringent earthquake-resiliency standards. However, the country has abundant 3D technologies, including nationwide digital mapping of its landscape and infrastructure through the Plateau project since 2020. Shizuoka Prefecture was the first in Japan to create "digital twins" in 2017, and they were used for a rapid assessment of mudslide damage in 2021 (Shino 2021). In Tokyo, a pilot is underway to display real-time flood forecasts on digital maps of downtown Tokyo to facilitate evacuation (Seto et al. 2023; Sekine et al. 2020).

Japan also follows Singapore and South Korea in building data-driven "smart cities" equipped with sensor technologies, including microgrids for energy self-sufficiency, which is critical during disasters (Kim et al. 2023; Haslam 2015; Soon and Khoo 2017). These technologies for emergency response will complement Japan's expertise in disaster detection and elevate its humanitarian and development contributions, including the work of JICA's Japan Disaster Relief personnel, who are dispatched to provide rescue and

emergency medical support (Okita et al. 2018). Blockchain enhances aid accountability and low-cost and durable 3D-printed shelters, easing housing needs in congested Asian cities, both short-term and long-term.

5 FUTURE DIRECTIONS

This case study has demonstrated Japan's commitment to engaging in science diplomacy, which serves as the technological foundation for utilizing remote sensing and AI-enabled predictive analysis, as well as making new investments in blockchain and 3D printing to enhance transparency and expedite aid delivery. These innovations exemplify the cutting edge of emergency management, with the potential to transform response strategies through improved predictive capabilities, efficient resource allocation, and equitable distribution of aid.

Japan is positioned to be the main driver in fostering collaboration and enhancing disaster resilience in Asia, an area that generally lacks comprehensive regional cooperation frameworks. Its science diplomacy has promoted technical cooperation, even with countries experiencing political instability domestically and with neighbors. Increasing these efforts with additional innovations to improve crisis communication and management, including sharing expertise with international organizations, will be essential for regional stability as future disasters caused by change are expected to become more frequent and severe.

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