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EDITORIAL

This issue comes out in the wake of the successful conduct of the G20 Leader's Summit meeting in New Delhi, 9-10 September 2023 and the end of an eventful and productive Indian G20 Presidency. This was a landmark Summit coming after an impressive and unprecedented number of meetings and discussions conducted all across India, involving diverse stakeholders. The theme of One World, One family, One Future, guided the deliberations. The Indian presidency launched a number of new initiatives for the G20, while managing through skilful diplomacy to obtain a consensus Leaders Declaration, despite serious geopolitical divergences. There was widespread appreciation of the way the Indian presidency had managed the entire exercise, steered the African Union's entry into the G20, and enhanced the role of the global South.

Our issue presents an article that surveys the Science Technology and Innovation content of the G20 under the Indian Presidency, building on the work done in earlier years, while adding new elements. The Leaders' Declaration has three sections that are especially relevant, covering health and food, green development, and technological transformation. The G20 represents a formidable force for deploying STI solutions for tackling global challenges and accelerating sustainable development.

We also present an article on the rare earth resources and related supply chain issues and the role of the G20. The importance of robust and resilient supply chains for resources that are critical for meeting development challenges cannot be overemphasized. The impact of geopolitical rivalries on these supply chains presents a challenge.

Another article presents the experiences of international training programmes on Science Diplomacy conducted online. This mode of delivery has become increasingly important during the Covid pandemic. The technological and pedagogical challenges involved have been brought out by the authors. Overall, the experience has been very positive and we can look forward to improved courses in the future. It is important to have mechanisms that result in greater participation from the global South.

We also present an article on Science Diplomacy specific to Agricultural research in India. India is a leading agricultural and food producer and home to a wide variety of agroclimatic zones and a diverse ecology. Its experiences in Agricultural research are therefore relevant to the needs of many countries, especially the global South. Bilateral and multilateral means of collaboration are surveyed in this article.

The Covid pandemic has brought home the risks posed by mutating pathogens. Such mutations can occur in nature, and result in pathogens leaping across the species barrier to infect humans. Research activities that deliberately induce mutations in pathogens to study gain of function also pose risks for example of accidental release into the ecosystem. The Bioweapons Convention that is up for revision needs to take into account the risks to biosecurity and biosafety arising from technology advances. A modern inclusive approach to managing biosecurity across all species is needed.

Another important is the rapid advances in synthetic biology coupled with the use of powerful information technology tools such as AI. We present an article that looks at the promises and the challenges emanating from this advancing technology and the international response. The issue includes a book review of the *Science Diplomacy: Foundations and practice* edited by Simone Arnaldi.

We continue our efforts through our Science Diplomacy programme at RIS to provide a platform for exchanges of research and views on various facets of Science Diplomacy, especially its key role in addressing global challenges, including sustainable development.

ARTICLE

Online Training and Capacity Development in Science Diplomacy: Sharing Experiences

Katharina Höne* and Pavlina Ittelson**

Katharina Höne

Pavlina Ittelson

Introduction

This article summarises the authors' experiences with developing and running an online course on science diplomacy offered by DiploFoundation (Diplo) in 2021 and 2022.[1] It highlights the course's context, development, content, objectives, delivery methods, participant feedback, and follow-up activities. It also draws on the feedback received from the course participants in the anonymous course surveys, which took place right after the end of the 2021 and 2022 courses. These points are discussed in relation to the relevant literature on science diplomacy and to delivering training and capacity development online.

As an organisation working in the area of capacity development for diplomats and international relations professionals, Diplo has already done some research on science diplomacy (Höne & Kurbalija, 2018; Ittelson & Maduit, 2019), related to the focused areas of events and training (DiploFoundation, 2019; Andrijevic, 2017; Kurbalija, 2015). Early on, there was a clear recognition of the need to integrate the science diplomacy topic into the organisation's work to deliver contemporary, reflective, and practical training.

More importantly, science diplomacy provided a useful lens through which to view global challenges and the concrete tools available to address them. The COVID-19 pandemic and mounting evidence of the urgency of addressing climate change further highlighted the importance of science diplomacy training and its role in solving some of

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the world's most pressing challenges. Understanding science diplomacy as a practice that addresses global challenges is an established perspective (Fedoroff, 2009). Two additional elements are crucial: science diplomacy as a boundary problem (Kaltofen & Acuto, 2018), and advice for spanning this boundary and working on the science-policy interface (Van den Hove, 2007; Bednarek, 2018). At the same time, the authors are also mindful of the potential hype around science diplomacy (Kurbalija, 2022), which raises concerns about conceptual vagueness and practical ambiguities (Flink, 2022).

Context

Diplo is a non-governmental organisation and has been delivering online training and capacity development to professionals for over 20 years. One of the foundational aims of Diplo is to support small and developing countries in areas related todiplomacy and digital policy, technology, and internet governance on the other. A number of courses, of which the Science Diplomacy course is a prime example, are located at the intersection of the two areas. Core course topics include among others, bilateral and multilateral diplomacy, economic diplomacy, the diplomacy of small states, humanitarian diplomacy, sustainable development diplomacy, public diplomacy, e-diplomacy, internet technology and policy, artificial intelligence, and cybersecurity. Altogether, more than 7,200 participants from 208 countries and territories have been trained over the past 20 years.

In 2022, Diplo delivered 29 courses involving more than 700 participants, with a typical course duration of 10 weeks. The courses are characterized by a small-scale format, usually involving a maximum of 25 participants, and are designed to foster a high level of interactivity. (see 'Delivery methods and pedagogy' below). In 2022, 68 per cent of course participants were diplomats or civil servants. The participant breakdown further includes 13 per cent representatives from civil society, 7 per cent staff of international organisations, 5 per cent representatives of business, and 6 per cent from academia.

This organisational profile provides the context and general framework in which the Science Diplomacy course was developed and delivered. To mention a few key points; First, Diplo's typical audience consists of working professionals, usually at an early or mid-career stage; hence, the course workload always needs to be at a level that is compatible with full-time employment, and there needs to be sufficient flexibility regarding course tasks. Second, the majority of participants are diplomats or civil servants, which has to be taken into account when designing this particular science diplomacy curriculum. This concerns the balance between 'theory' and 'practice', the level of assumed previous knowledge regarding diplomatic practice, international organisations, as well as scientific practices and processes. Third, aiming to support small and developing countries, sustainable development, and the sustainable development goals (SDGs) were included prominently from the start.2 Since the course is held online, it allows for the participation of a wide variety of participants who may otherwise not be able to access courses that would require in-person participation and travel. It goes without saying that the perspectives of science diplomacy practices and practitioners from the Global South were included in the course materials and lecturer selection. Great care was taken to ensure a safe space for the participants to exchange their own expertise on the matter.[3]

The course was launched within a wider field of online training opportunities in science diplomacy. Currently, there are a number of self-paced courses and resources available for free. This includes (a) the European Science Diplomacy Online Course developed by the S4D4C consortium (S4D4C, n.d.), and now maintained by the European Union Science Diplomacy Alliance; (b) introductory resources on science diplomacy developed by the American Association for the Advancement of Science (AAAS) (American Association for the Advancement of Science, n.d.); and (c) resources on international scientific cooperation in the Arctic provided by the UN Institute for Training and Research (United Nations Institute for Training and Research, n.d.). There are also workshop-focused summer schools offered by AAAS and the World Academy of Sciences (Serra, 2022) and the Barcelona Science and Technology Diplomacy Hub (SciTech DiploHub, n.d.) that went online as a response to the COVID-19 pandemic. Two prominent university programmes are also worth mentioning: the Science, Technology, and International Affairs (STIA) programme at Georgetown University and the various routes as part of the Masters of Public Administration offered by University College London (UCL, n.d.). Regional capacity-building initiatives and courses have been launched in recent years. Since 2017, a yearly in-person course on science diplomacy with a particular focus on South-South cooperation has been taking place under the auspices of the Indian Technical and Economic Cooperation Programme of the Ministry of External Affairs of India. The São Paulo Innovation and Science Diplomacy School (InnSciDSP), set up as part of the foreign policy priorities of Innovation Diplomacy under the Ministry of Foreign Affairs of Brazil, is another example (Innovation and Science Diplomacy School, n.d.). There are also initiatives that aim at science diplomacy capacity development, such as the Science Diplomacy Capital for Africa (SDCfA, South Africa), the Science Diplomacy Center at the Inter-American Institute for Global Change Research (Uruguay), and a TWAS Arab Regional Partner (AREP) workshop focused on Arab countries. In addition, science diplomacy has been integrated into university degrees (Mauduit & Gual Soler, 2020; Robinson et al., 2023).

Course Development

Course development started in early 2021 and was highly collaborative. The course was designed, developed, and delivered in partnership with the National Science Policy Network (NSPN), based in the USA, through their SciDEAL fellowship. The NSPN is a membership nonprofit of science students and early career professionals that aims at the inclusion of their members in policymaking processes. Through the fellowship, Diplo could match with five fellows from different areas of science (environmental science and anthropology, virology, climate and energy, palaeontology, and environment and sustainability). These fellows were involved throughout the course development and course delivery to allow them to build their skills and knowledge about how courses are designed, the process of drafting and preparing materials, and what considerations, besides academic ones, need to be in place for viable course launch and delivery. Each of the fellows prepared texts for one of the course modules from their field of expertise. The fellows had the chance to participate in the delivery of the course and to observe how the materials they had prepared for the course were interpreted by the participants. They could exchange with professionals from different areas and nonscientists on the content and learn through exchanging opinions. Working with the fellows was an enriching experience for Diplo, as well as for the fellows, through building on each other's methodologies and knowledge, being involved in high-level discussions on science diplomacy, and exchanges on the value of science in diplomacy and diplomacy in science.

In addition to collaborating with the NSPN, Diplo also involved two Geneva-based organisations: the Geneva Science and Diplomacy Anticipator (GESDA) and the Geneva Science-Policy Interface (GSPI). Geneva, where Diplo is also based, has a rich ecosystem of organisations working in science diplomacy (not to speak of the various international organisations that are examples of science diplomacy in practice). Hence, the development of the course and its content are needed to reflect this ecosystem. Both GESDA and the GSPI contributed one module each, which reflected the organisations' work in the area of science diplomacy anticipation and at the science-policy interface, respectively.

In developing the course and as discussed in the previous section, Diplo was mindful of existing online courses and training opportunities, the particular audiences the courses usually attract, and the organisational aims.

Course Content

The initial ten-week course comprised eight substantive modules, each taking up one week of the course and focusing on a specific aspect of science diplomacy. The course also included an introductory week and one final week for completing the final course assignment.

The course content, broadly speaking, follows the following logic: (1) initial introduction of science diplomacy ; (2) an evaluation of science diplomacy in the context of the SDGs; (3) an exploration of specific areas and topics of science diplomacy (in relation to the SDGs), such as climate change, are explored; and (4) the final two modules focus on developing skills to navigate the science-policy interface, and thereby addressing some of the challenges identified in previous discussions, and exploring the anticipation of emerging science diplomacy issues.

In detail, the eight substantive modules (DiploFoundation, n.d. a) of the course are:

1. Introduction to Science Diplomacy: This module asks and answers five main questions: What is science diplomacy? Who is practising science diplomacy and how? What are the main skills needed? What does science diplomacy from the Global South look like? And lastly, what is science? While the course discusses various definitions, it also pays attention to recent developments in science diplomacy practice.

2. Science Diplomacy and the SDGs: This module takes the understanding of science diplomacy developed in module one and applies it to the specific context of the SDGs. The module unpacks the role of science in and for the SDGs, and sheds light on specific science diplomacy interactions.

3. SDG 3 – Good Health: This module is the first of four modules focusing on a specific SDG. The module highlights why it is so crucial that science and diplomacy interact to achieve the SDGs. It pays particular attention to recent developments, discussions, and achievements in addressing the COVID-19 pandemic.

4. SDG 7 – Renewable Energy: The module surveys the scientific concepts

and tools related to renewable energy and discuss case studies highlighting science diplomacy interactions.

5. SDG 13 – Climate Action: The module explores climate science and the diplomatic setbacks, as well as breakthroughs in addressing climate change globally. Key moments of interaction between science and diplomacy in the field of climate action are further discussed.

6. SDG 15 – Life on Land: This module focuses on land change in the context of sustainable development. Key diplomatic milestones, such as the 1992 UN Conference on Environment and Development (UNCED) and the UN Convention to Combat Desertification (UNCCD) are discussed alongside scientific tools such as remote sensing and modelling.

7. Navigating the Science-policy Interface: Following the discussion on science diplomacy in the context of four SDGs, this module, developed by GSPI, sheds further light on science diplomacy interactions and how to successfully approach and conduct them. It gives practical advice on navigating the science-policy interface.

8. Anticipation of Future Science-policy Interactions and Challenges: This final module, developed by GESDA, focuses on anticipation and future developments in science-policy interactions. The module discusses approaches to anticipation and concludes with a hands-on exploration of anticipation tools.

In 2022, Diplo delivered a shorter version of the course, comprising four modules: 'Introduction to science diplomacy', 'Science diplomacy and the SDGs', 'Navigating the science-policy interface', and 'Anticipation of future science-policy interactions'. The decision to offer a condensed version of the course reflected feedback received after the first iteration of the course. Some participants felt that the commitment of ten weeks was slightly too much. The course survey after the first course indicated that 43 per cent of the participants found the coursework too heavy. This was a clear signal to address the workload in future iterations of the course. While participants enjoyed learning about science diplomacy examples from various fields – such as climate change or health – some feedback indicated that the materials were too basic. In contrast, others indicated that the material was too difficult. Given the various fields that participants came from, this feedback made clear that it is challenging to find the right level at which to pitch information on various fields to a diverse audience.

Other feedback on the course highlighted the relevance of framing the discussion in terms of the SDGs and the contribution of science diplomacy practices to specific SDGs. For example, when asked what they liked best about the course in the post-course surveys, some course participants indicated the focus on the SDGs as something that stood out to them – either in terms of gaining a better understanding of how science diplomacy, in general, can help to achieve the SDGs or in terms of discussing specific SDGs through the science diplomacy lens.

When discussing course content, it is useful to distinguish between content-based knowledge and skills-based knowledge (Mauduit & Gual Soler, 2020). Ideally, training in science diplomacy pays attention to both kinds of knowledge. As part of the skills-based knowledge provided by the course, participants discuss the skills needed by both diplomats and scientists, self-assess their level of competency, and identify areas they wish to improve. Beyond self-reflection, the course also provides an opportunity to critically engage with the skills typically listed for science diplomacy (Melchor, 2020). Some of the questions raised included: What is missing from this list? Are we presented with an over-simplification (e.g. what about diplomats with strong scientific backgrounds)? Is a strict distinction between skills that diplomats need to acquire and skills that scientists need to acquire useful?

In addition, Module 7 makes a multitude of practical suggestions on how to work at the science-policy interface, such as boundary spanning as the practice of facilitating effective science-policy engagement and decision-making under uncertainty. However, on the whole, participants have few opportunities to actively practice these skills in the course. Being mindful that 'experiential learning methods such as role-play simulations and interactive case studies' (Mauduit & Gual Soler, 2020) are considered the gold standard of science diplomacy skills development, it is planned for future iterations of the course to include stronger opportunities for science diplomacy skills development.

In organising science diplomacy knowledge, there is a distinction made between a thematic versus a cross-cutting approach (Mauduit & Gual Soler, 2020). This is common in existing science diplomacy education and training. Examples include the above-mentioned European Science Diplomacy Online Course and a number of textbooks on the topic (Davis & Patman, 2015). Mauduit and Gual Soler (2020) identify three elements of the cross-cutting approach: 'science policy and diplomacy fundamentals', 'international engagement in science and technology', and 'science diplomacy in practice' (Mauduit & Gual Soler, 2020). Diplo's course is a hybrid between the two approaches. The ten-week course follows a thematic approach for five of the eight modules. The introductory module, the module on the science-policy interface, and the anticipation module fall into the cross-cutting category.

The reasons for this structure can be located in the genesis of the course and Diplo's specific priorities. In Diplo's view, neither of these two approaches is inherently preferable to the other, but most learning opportunities arise in a hybrid of the two approaches.

Objectives

Keeping Diplo's targeted audience and organisational aims in mind, the course objectives were defined as follows (DiploFoundation, n.d. b):

Explain the main ideas and concepts of science diplomacy

- Have a broad overview of the various actors
- Understand its relevance for the SDGs
- Pinpoint the various ways in which science and policymaking interact
- Understand and contextualise evidence-based decision-making
- Have an overview of skills and practices that foster science diplomacy and science-policy interactions
- Apply the knowledge and skills gained in this course in the participants' fields of work

The 2022 iteration of the course was attended by participants from 12 countries, with

70 per cent of participants from developing countries, 20 per cent from developed countries, and 10 per cent from the least developed countries. The course surveys indicated that 100 per cent of participants found the course useful for their area of work and that 90 per cent of

participants would definitely recommend the course to someone else. In 2021, more than 90 per cent indicated that the course fully met or exceeded their expectations.

Delivery Methods and Pedagogy

The course is delivered through Diplo's customised online learning platform, where most of the interactions, apart from the weekly course meetings, take place. As mentioned, the class learns the material together, progressing to the next module in the course every week. These weekly cycles give structure and allow for a sense of learning community while adding as much flexibility as possible. Participants have three core tasks within a weekly cycle: (a) to read and discuss the week's lecture text and watch and discuss any video material; (b) to complete the weekly assignment, which could be a short essay assignment or a multiple-choice questionnaire; and (c) to attend the weekly course meeting which lasts for one hour. Apart from the weekly course meetings, all of these activities are undertaken asynchronously, adding to the flexibility of the course and catering to the fact that participants come from a variety of sometimes widely diverging time zones.

Diplo's methodology emphasises collaborative learning and joint knowledge construction. The discussion of the lecture text is at the core of putting this into practice. For this purpose, Diplo developed and uses a tool called 'textus annotations' or TAs. The TA tool allows participants to highlight and comment on any part of a text. Other participants can respond to these comments. Through this practice, discussion trees emerge that allow participants to deepen discussions in the areas of most interest to them. These discussion trees are the embodiment of Diplo's approach to joint knowledge construction (Kurbalija *et al.*, 2004) and also serve as a record of the discussion for future reference. Participants are required to add at least four TAs every week to gain full marks for participation. Lecturers read and respond to these TA comments on a daily basis with the aim of answering questions, adding clarifications, prompting further discussion, and weaving various parts of the discussion together. In the Science Diplomacy course, lecturers aim to add at least one response per participant per week. Feedback in the course surveys further highlighted the usefulness of this tool from the perspective of participants. One participant responded that the TA discussions 'enabled us to record and read through and debate each person's thoughts and ideas as we read through the course'. Another person suggested that TAs served as 'a great discussion platform over the text material, very enriching and eye-opening'. Having said this, a minority of participants identified the weekly class meetings via videoconferencing as the most useful tool for interaction and learning. This further underscored the importance of adding a variety of forms of interaction in any online course to cater to various learning preferences.

Follow-up Activities and Building a Community of Practice

Training and capacity development cannot end with the end of any particular course. To be effective in a longer-term perspective, follow-up activities are important. Such a community of practice emerged after the first science diplomacy course in a self-organised manner and through efforts targeted by the course organisers. On the self-organised side, one course-participant started to build a dedicated group on LinkedIn. Another participant, with logistic support from Diplo, organised a discussion on the film Don't Look Up and its lessons for science diplomacy (Zaqsaw, 2022). On Diplo's side, a book with contributions from course participants on science diplomacy in the context of their current and future work was published. The publication Science Diplomacy Capacity Development: Reflections on Diplo's 2021 Course and the Road Ahead (Höne, 2022) contains 30 reflections from course lecturers, course contributors, and course participants. By bringing both lecturers and participants together to reflect on the experience and the road ahead, a strong sense of community ensued, and the experience was documented for future reference.

Lessons Learned and Way Forward

In a nutshell, our thoughts on the next steps and lessons learned include the following key points:

- Diplo will continue to offer the science diplomacy course at least once a year,
- Diplo will continue to offer shorter courses and will also aim to offer à la carte choices on modules to cater to various interests,
- Including various guest lecturers from various professional backgrounds has proven extremely useful,
- Follow-up activities and community-building are crucial but also resource-intensive,
- Given available resources and interest, Diplo aims to include more aspects of skills-building in the course, particularly through role-play and simulation games,
- Feedback received after the first course also indicated a desire to engage in group work, which we will include in future course iterations; and
- Lastly, to further facilitate interactions at the science and diplomacy boundary, practices such as pairing diplomats or policymakers with scientists, for example, done as part of the AAAS and TWAS summer school, can be useful and are worth considering (S4D4C, 2021).

Science diplomacy offers many tools to address some of the most pressing global issues. It also allows for reflections on the challenges faced in, for example, responding to a pandemic or addressing climate change globally and developing avenues to improve global and local responses to these issues in the future. Because of the high stakes, capacity development and training efforts need to reflect the highest standards of content development and pedagogy. We hope this article further contributed to the discussion and clarification of these questions.

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Endnotes

1 The next iteration of the online course will be offered in October 2023. For more information, visit https://www.diplomacy.edu/course/science-diplomacy/

2 We are mindful of the fact that the SDGs, in contrast to the millennium development goals (MDGs), are aimed at developed and developing countries alike. Our experience, corroborated by feedback in the course surveys, has shown that discussing science diplomacy in the context of the SDGs is of particular relevance for participants from small and developing countries.

3 Feedback after the first iteration of the course indicated that some modules were still read as too centred on the Global North. We addressed this in the second iteration of the course.

ARTICLE

Synthetic Biology and the Next Wave of Science Diplomacy

Pawan K. Dhar* and Krishna Ravi Srinivas**

Pawan K. Dhar

Krishna Ravi Srinivas

Introduction

Science diplomacy involves leveraging scientific collaborations between countries to tackle shared challenges confronting humanity in the 21st century and to foster positive international alliances (Fedoroff, 2009). The role of Science Diplomacy in emerging technologies is recognized although there are not many initiatives in Science Diplomacy that focus on emerging technologies and the literature on this is quite limited. One reason could be that traditionally Science Diplomacy is associated with science per se, mega-science projects, and international collaboration in science. On the other hand, in this era of technoscience-driven Science, Technology, and Innovation, the potential of Science Diplomacy in contributing to the development of emerging technologies, their governance and adoption needs to be explored and realised.

But in the context of the war in Ukraine scenario the role of and scope for Science Diplomacy became contentious.[1] Another issue is that those who do research and write on the global governance of Synthetic Biology, hardly assess the potential of Science Diplomacy, perhaps because there are not many successful examples of Science Diplomacy's engagement with emerging technologies. Still, as "Emerging technologies pose several challenges to diplomacy: 1) they deal with many scientific fields and have diverse applications, some unknown, 2) they have the potential for serious national security risks, risks that are constantly evolving, and 3) they are the subject of tensions across nations. These challenges call

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for a role for science diplomacy in all three dimensions of the AAAS and Royal Society New Frontiers in Science Diplomacy framework. If science diplomacy is to be an effective tool for using scientific knowledge, scientific expertise, and/or scientific engagement to accomplish concrete objectives related to emerging technologies, then the immediate task is to specify the objectives sought and the means for achieving them."[2]

In this paper, Synthetic Biology is taken as an example to argue that Science Diplomacy can play a key role in addressing many issues related to Synthetic Biology, if not resulting in the development of globally acceptable solutions. While Synthetic Biology is developing fast, the regulations are not keeping pace with that, and the global governance of Synthetic Biology will likely be a patchwork of governance regimes without any binding treaty or convention to regulate it. For example, there may be a Protocol under the Convention on Biological Diversity (CBD) regulating Synthetic Biology, similar to the Cartagena Protocol (CP) under CBD. But as CP is limited to Living Modified Organisms its mandate cannot cover Synthetic Biology. Science Diplomacy's role can encompass multiple aspects of global Synthetic Biology, particularly in capacity building, reinforcing trust and confidence, and harnessing Synthetic Biology. We argue that there is good potential for India to use Science Diplomacy imaginatively in this.

The origin and evolution of Synthetic Biology

A. The Need for a New Kind of Science: In a general sense, two primary methodologies in scientific inquiry exist i.e., reductionism and integration.

Reductionism involves characterizing a system based on its constituent parts. For instance, when attempting to elucidate the behaviour of a complex organism, researchers dissect organisms to examine their internal makeup, aiming to gain insight into their higher-level functions. In eukaryotes, this could entail dissecting the body to analyze the interconnections between organs (gross anatomy). With the development of technologies, deeper layers of biological constructions were uncovered. Terms like histology, cell biology, molecular biology, and biochemistry were coined to indicate a progressively increasing resolution of biological construction.

Owing to the remarkable achievements in delving into the depths of biology and extracting insights from low to high throughput, huge data sets were generated that required massive *integration* using computer-assisted approaches that involved storage, annotation, querying, analysis, reporting, security, and more of biological data produced from reductionistic approaches.

More than twenty years ago, people wondered if a third approach could find a way in the biological sciences i.e., the *construction of biological systems from scratch*. This inquiry aimed to develop an engineering approach to constructing complex biological systems from a set of standard DNA parts library.

B. Building Scientific Foundation Synthetic Biology: The initial proof-of-the-concept came in early 2000 when a genetic toggle switch and a three-gene circuit called a repressilator were reported. The idea was to chemically synthesize genomes, cellular organelles, and whole cells as a ground-up construction process. This led to the first conference at MIT (June, 2004) signalling the emergence of a novel field called *synthetic biology*. As the new approach involved creating a standard parts library, people also used the term '*Biological Engineering*', as a proxy for Synthetic Biology, as it looked closer to real practice than theoretical understanding.

Essentially Synthetic Biology indicates a rational design and construction of biological components leading to a novel product – the product may be a design or a molecule.

The origins of the engineering-inspired approach can be traced to the similarities between biology and engineering. However, there are also key differences between them that make the pursuit of engineering biological systems, unique and more challenging (Table 1).

Table 1: A Quick Comparison between Biology and Engineering

	Biology	Engineering
Similarities	robust, non-linear, multi-tasking, fault-tolerant, complex, serial and parallel, adaptable	
Differences	mobile components, predominately analog, standards lacking, noise used	anchored components, predominately digital, standards well established, noise-filtered

Due to the unpredictability of biological engineering, the ability to construct novel devices, circuits, and organisms comes with more challenges and responsibilities.

It is crucial to emphasize that Synthetic Biology diverges significantly from recombinant DNA technology, which primarily relies on combinations and statistical likelihoods of designs stably working in a given host. While Synthetic Biology draws inspiration from genome engineering, pathway engineering, tissue engineering, and directed evolution, it fundamentally operates on the foundation of established standards and construction principles. These principles enable the precise engineering of cellular components and even entire multicellular systems.

Essentially, key tools used in Synthetic Biology comprise long DNA synthesis, DNA editing, high throughput screening platforms, and so on (Table 2). These are in addition to the standard tools used by researchers such as electrophoresis, cloning, transformation, blotting, sequencing, metabolomics, transcriptomics and

Table 2: List of Key Tools Used in Synthetic Biology

	Tools	Key references
1	**DNA writing** *(long DNA synthesis)*	Kosuri & Church (2014), Eisenstein (2020)
2	**DNA editing** *(CRISPR Cas9 and beyond)*	Doudna & Charpentier (2014), Doudna (2020)
3	**High throughput screening** *(automated strain engineering platforms)*	Wang *et al* (2009) Iwai *et al* (2022)
4	**Chemical biology** *(synthetic chemistry, cell-free systems)*	Endo *et al* (1977), Yue *et al* (2019)
5	**3D culture** *(bioprinting, organoid, organ-on-the-chip)*	Dey *et al.* (2020), Mladenovska *et al* (2023)

proteomics technologies, bioreactor, computational biology, bioinformatics, systems biology, and so on.

In this context, it may be relevant to underline our work on making novel biomolecules from the dark matter of the genome (Dhar *et al.*, 2009). The term 'dark genome' refers to non-expressing, non-translating, and extinct DNA sequences that can be artificially encoded into functional molecules. The non-expressing component consists of antisense, reverse coding, repetitive sequences, and intergenic sequences of DNA while the non-translating component comprises transfer RNA, noncoding RNA, ribosomal RNA, and introns. The extinct DNA sequences refer to pseudogenes that were active at one time in evolution but were retired over time.

C. **The Market impact:** The influence of synthetic biology on the market is substantial and continues to expand as the field progresses and novel applications emerge.

Researchers are crafting engineered microorganisms proficient in producing valuable substances like pharmaceuticals, enzymes, biofuels, and specially chemicals with heightened efficiency. The capacity to engineer biological systems for drug discovery is an incredible upgrade over traditional genetic engineering practices.

Synthetic biology stands poised to facilitate the cultivation of genetically modified organisms possessing enhanced attributes, such as elevated crop yields, resistance to pests, and augmented nutritional value. Engineered microorganisms can be harnessed to generate alternative sources of protein and other constituents for food production. Likewise, the large-scale manufacturing of bio-derived materials, encompassing bioplastics, textiles, and bio-based chemicals, can be enriched through the application of synthetic biology methodologies. Scientists are also working towards the possibility of fabricating organisms capable of remedying pollution, ameliorating contaminated sites, and bolstering endeavours towards environmental sustainability.

The horizons of synthetic biology are poised to continuously broaden, propelled by the global advancement in biological knowledge, decreasing costs associated with DNA writing and editing, and the increasing accessibility of synthesizing tools.

Much like how synthesis brought about transformations in chemistry and chip design that revolutionized computing during the previous century, biologists have capitalized on progress in molecular, cellular, and systems biology to fundamentally reshape the discipline from one of analysis to one of engineering.

As we approach the close of this decade, there's a strong likelihood that synthetic biology (SynBio) will find widespread application across manufacturing sectors that collectively contribute to over a third of the world's total output, equivalent to nearly $30 trillion in terms of value (Candelon F *et al.*, 2022). Analogous to the way synthesis reshaped the field of chemistry and chip design revolutionized computing during the past century, biologists have leveraged progress in molecular, cellular, and systems biology to fundamentally reshape the discipline, transitioning it from an analytical focus to a bona fide engineering discipline.

D. **The Ethical, Legal, and Social Implications (ELSI) Paradigm:** The elegance of synthetic biology (biological engineering) lies in its capacity to accommodate innovation across a broad spectrum. Therein lies in the opportunity and challenges from ELSI of a new kind of science that goes beyond studying natural systems and focuses on generating new designs in the lab.

To bring synthetic biology on a level playing field, it is important to have a crisp definition that finds acceptance across sectors and geographies. For example, a *chemical engineer* may consider synthetic biology as an approach to installing innovative controls in biomolecular pathways. A *metabolic engineer* may perceive synthetic biology as a science of introducing new metabolic pathways or tuning existing ones. A *molecular biologist* may see Synthetic Biology as an approach toward the construction of biological standards, synthesising genome, installing logic gates in the cells, and building tools for DNA editing. An *organic chemist* might look at synthetic biology as an opportunity to synthesize chemicals and biochemicals using microbial factories, or the creation of non-ATGC functional DNA. For a s*ystems biologist*, synthetic biology might entail process analysis of studying how cells organise complex massively parallel, and interactive processes, utilizing nature's designs to construct novel and stable networks.

Individual interpretations can differ, but it's vital to establish a clear differentiation between 'genetic manipulation' and 'genetic construction'. This differentiation aids in recognizing gaps in understanding and enhancing regulatory frameworks. It's advisable to address terms like 'Unintended consequences' and 'Unpredicted events', as they could foster unrealistic scenarios and impede sound scientific progress. The Centre for Biodiversity lists several key definitions of synthetic biology in its 2015 report.

- *Synthetic biology aims to design and engineer biologically based parts, novel devices, and systems – as well as redesigning existing, natural biological systems.'' (Kitney and Freemont, 2012)*
- *Synthetic biology … combines elements of biology, engineering, genetics, chemistry, and computer science. The diverse but related endeavors … rely on chemically synthesized DNA, along with standardized and automatable processes, to create new biochemical systems or organisms with novel or enhanced characteristics. (Wagner, 2010).*
- *Synthetic biology attempts to bring a predictive engineering approach to genetic engineering using genetic 'parts' that are thought to be well characterized and whose behaviour can be rationally predicted. (International Civil Society Working Group on Synthetic Biology, 2011).*
- *Synthetic biology aims to design and engineer biologically based parts, novel devices, and Engineering systems as well as redesign existing, natural biological systems. (The Royal Academy of Engineering UK, 2009).*

From an ethical standpoint, there are safety, dual-use dilemmas that touch the boundaries between living and non-living systems. Engineering life forms could pose dangers to health and the environment and raise concerns about possible outcomes. Changing life at the genetic level raises ethical questions about how we treat living things and where we draw the line between human action and natural processes.

Due to the creation of new biological entities in the lab, governments and international organizations need to make uniform standards for ensuring that engineered life forms are safely contained and released into the environment subject to restrictions and monitoring. The possibility of intentional harm may require regulations and protections to prevent potential bioterrorism.

The cost and availability of synthetic biology technologies could affect who benefits from them, raising questions about fair distribution. People's views and knowledge of synthetic biology may influence how people support or oppose it, requiring education and communication efforts. Synthetic biology may clash with some cultural beliefs and religious values, prompting discussions about how far one should go in designing or redesigning organisms.

It has been repeatedly emphasized that engineered life forms released into the environment could affect ecosystems in unexpected ways, posing difficulties for risk evaluation and ecological harmony. Addressing the ELSI aspects of synthetic biology is vital for fostering responsible research and innovation, promoting ethical practices, ensuring the safe deployment of technologies, and minimizing potential negative impacts on society and the environment.

The Global Diplomacy

As countries face complex challenges that transcend borders, scientific collaboration becomes a vital tool for addressing issues such as climate change, health crises, and technological advancements. The relationship between science and global diplomacy is symbiotic with both elements dynamically influencing each other.

A. **Foundational Concepts:** Global diplomacy refers to the art and practice of managing international relations, negotiations, and interactions between countries and international entities. It involves addressing various issues, including political, economic, social, and environmental concerns, through dialogue, negotiation, and cooperation. The aim is to promote peace, resolve conflicts, facilitate cooperation, and advance common interests. Science and global diplomacy are intertwined in a dynamic relationship that influences international relations, fosters cooperation, and drives societal progress.

B. **Science and Diplomacy:** The relationship between science and global diplomacy is symbiotic with both elements influencing each other dynamically. In the past when resources were less and only a few dominant players existed, global diplomacy impacted scientific pursuits in countries, using their national resources to develop socially useful innovations. However, with the rapid diffusion of technologies across the world, improvement of education, and economic situation, science and engineering sectors have seen significant national funding towards further strengthening economies. Due to the immense success of this strategy, recently we have seen examples of science such as climate change and a global outbreak of microbial diseases driving diplomacy.

Solutions rooted in scientific research can provide a common ground for countries to join hands and look for viable solutions. Scientific developments can guide policy decisions and help in bridging gaps within society.

Likewise, Diplomatic negotiations and international agreements can influence the direction of scientific research. Treaties related to environmental protection, arms control, Intellectual Property and trade have shaped research priorities and funding allocation. Diplomacy can foster an environment conducive to scientific cooperation, leading to the exchange of knowledge, resources, and expertise across borders. In this context, it is important to mention that international collaboration has provided funding for research projects that align with diplomatic objectives, such as promoting peace, addressing global health issues, or achieving sustainable development goals.

Essentially, the interplay between science and global diplomacy is a feedback loop. Scientific advancements provide the knowledge and tools needed to address global challenges, while diplomatic efforts create frameworks for collaboration, funding, and policy implementation.

In this context, it may be relevant to highlight several anatomical features of global diplomacy. Bilateral diplomacy involves direct communication and negotiations between two countries, with a focus on issues specific to their relationship. These matters encompass trade agreements, security arrangements, cultural exchanges, and more. Multilateral diplomacy, on the other hand, revolves around interactions among multiple countries within international organizations or forums. Examples include the United Nations, World Trade Organization, International Monetary Fund, and regional entities like the European Union and African Union. This approach strives to consider individual sensitivities and priorities while effectively addressing global concerns demanding collective action, such as climate change, disarmament, and public health. High-level meetings and discussions bring together leaders and diplomats from diverse countries to tackle specific issues or challenges. Notable diplomatic events, like the G7, G20, or ASEAN gatherings, exemplify forums that encourage dialogue and cooperation.

C. Synthetic Biology and Diplomacy:
The regulatory framework of Synthetic biology must be an outcome of dialogues occurring within international, regional, and privately driven arenas, reflecting diverse perspectives and interests. Numerous international agreements and organizations are presently assessing the ramifications of synthetic biology and engineered gene drive systems within the scope of their respective accords.

I. *Convention on Biological Diversity (CBD):* The Convention on Biological Diversity (CBD) has been ratified by 196 states. The United States of America (USA) is a non-party to the convention. USA refused to join the Convention as it had reservations about Access and Benefit Sharing under CBD. Synthetic biology is a new and emerging issue in the context of realizing the objectives of the convention. The twelfth Conference of the Parties (COP12) and COP13 produced decisions seeking a more robust assessment of synthetic biology against the Convention's new and emerging criteria[11]. The Parties decided to establish an Ad Hoc Technical Expert Group (AHTEG) and convened a moderated online forum.1 The AHTEG has produced multiple reports and recommendations but is yet to come up with a robust assessment against the new and emerging criteria as mandated by the COP12. At COP 14, Parties agreed on a need for regular horizon-scanning of the most recent technological developments for reviewing new information regarding the potential impacts of synthetic biology. (CBD, 2023).

II. *The Cartagena Protocol on Biosafety:* The CBD COP extended the AHTEG on synthetic biology, taking into account the work under risk assessment under the Cartagena Protocol on Biosafety. Current deliberations are also considering whether any living organism developed thus far through new developments in synthetic biology fell or could potentially fall outside the definition of a living modified organism (LMO) and thus be subject to the risk assessment requirements of the Cartagena Protocol on Biosafety (CBD, 2003).

III. *The Nagoya Protocol on Access and Benefit Sharing:* In 2017, the Secretariat of the CBD commissioned a report examining the impacts of digital sequence information (DSI) as it relates to the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the Convention on Biological Diversity. *Food and Agricultural (FAO): The FAO International* Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) report commissioned in 2017 examined the impacts of synthetic biology and digital sequence information (DSI) on the Plant Treaty. The report addresses the phenomenon of "dematerialization", defined as that "the information and knowledge content of genetic material extracted, processed and exchanged in its own right, detached from the physical exchange of the plant genetic material". It included the scientific and technological changes affecting the Treaty and the broader legal considerations and opportunities for benefit sharing within the ITPGRFA framework. (Welch, *et al.*, 2017)

IV. *Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES):* CITES has been engaged in discussion on the question of synthetic products that are indistinguishable from products from listed specimens and the status of modified organisms and products under the Convention. Seventieth meeting of the CITES Standing Committee in October 2018 adopted a report on the "Specimens Produced from Synthetic and Cultured DNA". The study notes that regulation under the treaty becomes challenging since synthetic biology specimens may be extremely difficult to differentiate from wild specimens by visual or analytical means.

V. *International Union for the Conservation of Nature (IUCN):* IUCN Members adopted a Resolution titled "Development of IUCN policy on biodiversity conservation and synthetic biology" to map the impacts on conservation and sustainable use of biodiversity. In early 2018, an IUCN Synthetic Biology and Biodiversity Conservation Task Force, was created to oversee the implementation of the Resolution and to develop policy recommendations before the 2020 World Conservation Congress.

VI. *Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS):* The focus under TRIPS, on issues related to synthetic biology, pertains to intellectual property rights issues. The results of current synthetic biology research that is focused on modifying existing "natural" genomes could qualify for the "breeder's right" under the International Union for the Protection of New Varieties of Plants (UPOV Convention) If, in the future, there are new plant varieties developed as a result of the production of entirely novel genomes, protection under breeder's rights needs to be discussed. It is also possible that they can be patented. For reasons of space, we are not elaborating on this further. It is worth pointing out that "Intellectual property is likely to be complicated as applications of synthetic biology involve several disciplines and likely will embody multiple patented inventions. Clear structures for managing intellectual property rights are important to promote continued innovation."[2]

VII. *UN Convention on the Law of the Sea (UNCLOS):* UNCLOS includes activities and resources beyond national jurisdiction. BBNJ treaty covering Marine Genetic Resources (MGR) and Access and Benefit Sharing (ABS) related to that has been ratified with eighty three signatories.3

VIII. *Liability for International Harm:* The international legal principle of state responsibility for international harm provides for liability for possible damages attributable to synthetic biology. The Nagoya-Kuala Lumpur Supplementary Protocol on Liability and Redress to the Cartagena Protocol provides for states to establish national frameworks for liability in cases of environmental harm.

Given the easy availability of communication pathways, science crosses national borders, making it important to harmonize regulations and standards. *Multilateral diplomacy must play a role in facilitating international agreements on regulatory frameworks in the development and deployment of emerging technologies*. There can be voluntary guidelines and other soft law instruments in regulation. While it takes a long time to negotiate and get treaties/conventions ratified they are essential for regulating Synthetic Biology globally. Legally binding Treaties are impossible without multilateral diplomacy and Science Diplomacy can contribute to Treaty-making process in the context of global regulation of Synthetic Biology.

The last two decades have seen the creation of new bio-based products and industries. It's time for diplomatic efforts to promote trade relationships, collaboration, and investment in the development of synthetic biology-related technologies.

Synthetic biology research needs to be collaborative, and international partnerships are essential to advancing the field. Diplomacy can facilitate the exchange of knowledge, expertise, and resources among researchers and institutions around the world. Diplomacy can contribute to the establishment of international norms and codes of conduct for synthetic biology research and its applications, ensuring that responsible practices are followed globally. It's about time to think of establishing frameworks to coordinate research, development, and deployment of lab-made designs and organisms.

Case studies

A. Jurassic Park

Biodiversity has been defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems"

The Earth's extensive global variety of life forms constitutes a vast reservoir containing nucleic acids, proteins, cells, tissues, and organisms that form intricate food chains and serve ecological functions. This encompasses tangible resources such as food, timber, and medicines, as well as critical ecological roles like flood control, temperature regulation, and nutrient cycling. Additionally, non-material benefits such as recreational opportunities arise from biodiversity. The significance of biodiversity is further evident in its contributions to agriculture, the facilitation of the carbon cycle, and the maintenance of human well-being. Moreover, it imparts robustness to environmental fluctuations and yields social and economic advantages.

Human activities have induced transformations in ecosystems, altering natural landscapes into urban landscapes dominated by concrete structures. The introduction of non-native species and the destruction of wildlife are among the consequences. Although ongoing endeavours seek to restore equilibrium, the decline of biodiversity continues at varied rates across the globe

Of late people are asking - Is Jurassic Park going to be a reality? In the future, we might witness the presence of woolly 'mammoths' freely traversing the Siberian tundra. Could the revival of creatures like dodos and dinosaurs be the next step in the process of de-extinction? Taking lessons from the Human Genome Project, computational biology and bioinformatics have evolved to the extent of writing a genetic code that fills in the missing DNA sequence links. Genome Editing and long DNA synthesis tools may help rewrite the genome of an Asian elephant to create a Mammoth!

From what we understand the de-extinction programs have already been started. Even if the rewritten genome does not entirely match the extinct animals, it would give enough starting material to reintroduce lost species to local habitats.

Some of the reports indicate dodo stands as a prominent contender for de-extinction, having been originally confined to Mauritius and succumbed to extinction during the 17th century following human settlement on the island. The loss of its habitat, coupled with the introduction of pigs, cats, and monkeys by sailors, compounded the threats the dodo faced. Theoretically, it may be plausible to incorporate dodo DNA into an evolutionarily related species. However, de-extinction projects must consider the non-availability of the habitat that the organism once enjoyed.

The Colossal project[6] is about the de-extinction of the woolly mammoth. The first step is to find a well-preserved sample of woolly mammoth from areas close to the North Pole. Following this building a full genome sequence, identifying cold weather genes, using gene edits to create suitable cell lines and animal models to test for various traits, transferring an engineered nucleus to an Asian elephant egg, and nurturing a pregnant elephant to give birth to an engineered woolly mammoth calf.

The precautionary principle should find application within the realm of de-extinction efforts. The consideration of international agreements becomes imperative for delineating measures to regulate and safeguard de-extinct species. Notable among these agreements are the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Convention on the Conservation of Migratory Species of Wild Animals, the Convention on Biological Diversity, the Cartagena Protocol on Biosafety to the Convention on Biological Diversity, the Paris Convention for the Protection of Industrial Property, the Patent Cooperation Treaty, the Patent Law Treaty, and various other international accords.

As strides are made toward the advancement of de-extinction endeavours, the global community should contemplate the wide-reaching legal ramifications inherent in de-extinction. An approach steeped in precaution should be embraced, steering discussions on how to oversee and safeguard species that have undergone de-extinction. Even if the specific invocation of the precautionary principle is not explicitly embedded within distinct international treaties, the foundational notion of early intervention encapsulated within this principle should guide responses to the myriad challenges that de-extinct species introduce.

To ensure the enduring survival of de-extinct species and preclude their re-extinction, proactive safeguards must be instituted. Anticipatory adjustments to the international legal frameworks safeguarding existing species could contribute to this objective. Essential regulations need to be established ahead of the introduction of de-extinct species into their natural environments, shielding against potential unintended repercussions akin to the narrative of Frankenstein's monster.

The stewardship and governance of de-extinct species could be achieved through the amendment of prevailing international treaties and agreements. Alternatively, the creation of fresh resolutions or analogous documentation within existing frameworks could also serve this purpose. It may even necessitate the formulation of a completely new treaty or agreement dedicated to the oversight and regulation of de-extinct species.

The most effective strategy likely involves a blend of these possibilities. Initially, proposing new resolutions to existing treaties might offer a viable route, while over the long term, crafting a dedicated treaty could be indispensable. Of course, there are country-specific issues that have to be looked into (Kuriakose, 2022).

Acknowledging that some nations might be hesitant to initiate profound adjustments due to the nascent nature of de-extinction, the discourse on this matter should commence without delay. While the future trajectory of de-extinction remains uncertain, the importance of acting preemptively cannot be overstated; erring on the side of early action is unequivocally preferable to responding belatedly.

B. Synthetic Meat

Cultured meat, also known as Synthetic meat or lab-grown meat, is a type of meat that is produced by culturing animal cells in a laboratory rather than by traditional animal farming methods. It is an emerging technology in the field of cellular agriculture, which aims to produce animal products without the need for raising and slaughtering animals. The aim is to deliver the sensory experience, meet nutritional requirements, and generate environmental sustainability without slaughtering animals.

Estimates indicate that >80 billion animals are globally slaughtered every year for food generating more than 40 per cent of global methane emissions, leading to climate change deforestation, and water scarcity.

Cultured meat technology has the potential to meet the key UN Sustainable Development Goals (2 and 13) of eliminating hunger, achieving good health, ensuring sustainable consumption and production, and combating climate change.

To feed millions of people and meet their dietary requirements, the livestock sector has been expanding incessantly significantly contributing to global warming. Estimates indicate that for the last six decades, global meat production has risen three times and is expected to reach 300 million tons by the year 2020 (Alexandratos & Bruinsma, 2012).

Overall, it seems the global demand for food production may increase by 70 per cent (latest UN estimates) due to population growth.

Given the highly connected world that we live in, meat produced in one country can easily find its place on the supermarket shelves of another country. Due to this reason, suitable global regulatory guidelines need to be developed to assess the environmental impact (energy consumption, waste management, water usage), Intellectual Property Rights (patent protection, licensing, technology transfer), International Harmonisation (global trade practices, food security diplomacy), standardisation of process, meat quality and manufacturing practices. Of paramount importance is the safety of the cultured meat (potential risks of contamination, unintended toxins and residues showing up in the cultured meat, presence of antibiotics). So regulation at national, regional and international levels to regulate these aspects is essential.

Given that cultured meat is far less polluting than farm-based, suitable carbon credits may be discussed with the possibility of exchanging them among countries.

The India Initiative

From the Indian perspective, probably the first step in synthetic biology was taken when Indian teams presented their designs at the iGEM competition (MIT) in 2006.

Towards the end of the decade, the first synthetic biology conference (Biodesign India) was held at the Centre for Systems and Synthetic Biology, University of

Kerala in October 2010 to identify the emerging synthetic biology community in India. This conference crystallized an interest group "SynJeevani" from State universities, Central universities, IITs, and National Research Labs. The second synthetic biology event was held in Dec 2012 at Jawaharlal Nehru University with representation from the University of Washington and the US National Science Foundation. The outcome of this event was an appreciation of an urgent need to start academic and research programs in synthetic biology. In 2014, a major DBT and NSF (USA) sponsored Indo-US conference and workshop on Synthetic and Systems Biology was organized at JNU. This event brought together speakers from the US and India, a large student and scientific community from India. Several exciting collaborative ideas were discussed between the US and Indian synthetic biology communities. A special DBT brainstorming session was held (during this meeting) to explore the road ahead for India, leading to a concrete future action plan. In 2017, an International Biological Engineering Meeting was held at JNU with support from NIPER Kolkata.

In 2018, DBT awarded the project "*Policy and Research Planning for Synthetic Biology*" to Jawaharlal Nehru University. The outcome of the project was an 85-page foresight document submitted to DBT for further deliberations and for building a comprehensive synthetic biology policy for India (Dhar & Balakrishna, 2020; Sathyarajan *et al.*, 2021).

In 2022, a new iGEM India League was initiated to make iGEM competition more accessible to students, academicians, professionals, and institutions. Focused on the Indian Subcontinent, the League aims to develop the Synthetic Biology Infrastructure and Education ecosystem.

Broadly speaking, in the context of Indian science, synthetic biology research has begun a bit slowly. Frequent interactions among scientists, students, and funding managers are needed to improve India's position in this sector globally. India needs to launch major scientific and education programs in synthetic biology, along with a dedicated DBT task force on synthetic biology.

This vision is recognized in the 2011 Report of the Planning Commission constituted a task force on synthetic and systems biology resource network (SSBRN) which states that: "In India the Synthetic and Systems Biology is at a nascent stage… The timing is suitable for a well-supported 'push' into synthetic biology, both from the point of view of enabling technologies as well as looking toward practical applications. The immediate goal should be to build a base of research expertise and infrastructure in Synthetic and Systems Biology. Citing this, Srinivas pointed out that addressing regulatory, ethical, legal, and social issues is crucial to harness Synthetic Biology effectively (Srinivas, 2014).

Two recent key developments have emerged from India in the Synthetic Biology space. One is India joining the **Global Biofoundry Alliance** (Panda & Dhar, 2021a, 2021b) and the second is starting the **lab-grown meat** initiative (Dhar, 2023).

The Biofoundry India drive is an attempt to build a national maker space for building tools, standards, and applications in biological engineering. Using high throughput technology and automated workflows, it would be possible to test thousands of strain edits in parallel and select the right design for further development. Currently, there are no regulations regarding developing and operating Biofoundry. In the future it would be useful to plan along these lines, to ensure responsible innovation.

The cultured meat initiative has led to the commercial production of animal culture medium that does not require the addition of Fetal Bovine Serum (Gautam *et al.*, 2023). Clear Meat Pvt. Ltd. is the first Indian startup in this sector that has taken an early lead in this direction. Academia and Industry are waiting for the Government's clearance to manufacture lab-grown meat that is affordable, environment-friendly, nutritious, and ethical. The cultured meat technology has the potential to be a disruptor to feed the world and can be a good opportunity for multilateral diplomacy.

Moving to the future there is little debate that India's potential in using science for diplomacy remains under-utilized.

- India needs to commission detailed foresight/technology landscaping studies within the country and at the global level (QUAD, BRICS, ASEAN, Asia Pacific) to understand environmental and biosecurity challenges in synthetic biology. Globally regulatory guidelines specific to synthetic biology are lacking. It's time to bring the stakeholders from academia, industry, and society on a common platform and build a robust regulatory framework to ensure the protection of good science within a responsible innovation framework.

- The connotation of '*emerging technologies*' has shifted from its meaning three decades ago when it pertained to the early Internet. In contemporary times, it includes artificial intelligence, quantum computing, biotechnology, space technologies, and blockchain. These emerging technologies are pivotal to India's expanding domestic economy and digital landscape. However, they also bring along potential security vulnerabilities. As we find ourselves in an era of rapidly advancing technological frontiers, it becomes imperative to collaborate with experts, diplomats, and skilled professionals to formulate relevant policies. This collaborative effort serves to bridge the critical gap in terms of national security and domestic interests. It also involves a comprehensive assessment of the capabilities and potential applications of these technologies.

In this context, the New, Emerging, and Strategic Technologies (NEST) division within the Ministry of External Affairs (MEA) assumes a vital role.

The NEST division is instrumental in comprehending the strategic implications of disruptive and dual-use technologies on foreign policy and the associated international legal dimensions. This is achieved through dialogues with foreign governments and coordination with domestic ministries and departments. While India could face new security challenges due to these advancements, it's essential to recognize their potential as economic and geostrategic assets. These technologies can significantly transform livelihoods and governance. We suggest that NEST should explore the linkage between Science Diplomacy and Synthetic Biology and use Science Diplomacy imaginatively.

Future Pathways

1. There is a need for an international framework that defines the boundary conditions of synthetic biology toward safe and effective research. India can use Science Diplomacy to develop an international framework. For this India has to develop a coherent policy and strategy on Synthetic Biology with a focus on external engagement and initiatives to contribute to the global development of regulation of synthetic biology including standards and addressing biosafety and biosecurity issues.

2. *Convention of Biological Diversity (CBD):* The Ad Hoc Technical Expert Group (AHTEG) of CBD on synthetic biology has produced multiple reports but has yet to come up with a robust assessment and recommendations. There is a need for stakeholders from Academia, Industry, Government, and Social Interest groups to come together and collectively decide the way forward. The CBD process in Synthetic Biology has to be taken forward. The reports prepared so far can be assessed for their relevance for India and how India can use them in its international strategy on Synthetic Biology. After reviewing the developments in CBD and elsewhere on regulating Synthetic Biology, Weiss argues that the Precautionary Principle will be useful in regulating Synthetic Biology. (Weiss, 2020, p. 201). Given the developments under CBD, the best option would be to use CBD to develop suitable guidelines to regulate Synthetic Biology, with or without a separate Protocol.

3. The Self-regulation by people in academia/industry/hobbyists in the form of soft standards is neither binding nor legally enforceable so Synthetic Biology must be stringently regulated. However as the experience in biotechnology and other emerging technologies proves, the regulatory frameworks and priorities in regulation are not likely to be universal. India can take the lead by developing a robust, science-risk-potential-based regulatory framework that can be a good model to be adopted/adapted.

4. The de-extinction of organisms needs to be deliberated assessed for its impact on biological diversity and ecosystems. Its long-term impacts on ecosystems have to be a key consideration.

5. India can take a global lead in building an open-access system in synthetic biology. Open Science is a movement to make science more accessible, inclusive, and equitable for the benefit of all. The concept of open science calls for designing a system where research data, lab notes, and other research processes are freely available, under terms that enable the reuse, redistribution, and reproduction of the research and its underlying data and methods. In the spirit of Open Science, the world needs Synthetic Biology Commons a polycentric, multi-stakeholder alliance to ensure free access to a vast array of scientific data generated worldwide, similar to Genomic Commons (Contreras &

Knoppers, 2018). Building upon the experience with Genomic Commons as described by Contreas and Knoppers and other similar commons-based initiatives a Synthetic Biology Commons can be envisaged.

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Endnotes

1. For details, see https://blogs.lse.ac.uk/europpblog/2022/05/20/war-in-ukraine-highlights-the-enduring-myths-of-science-diplomacy/.
2. Visit https://www.sciencediplomacy.org/editorial/2022/emerging-technologies-and-science-diplomacy.
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4. Details available at https://agrifutures.com.au/wp-content/uploads/publications/16-035.pdf.
5. For details, visit https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXI-10&chapter=21&clang=_en.
6. More details at https://colossal.com/mammoth/.

ARTICLE

Science Diplomacy: A Tool to Tackle the Threat of Biological Weapons

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Introduction

The world is evolving with innovations across various fields, directly or indirectly impacting individuals, institutions, and states. One of the significant impacts of such innovation has been transforming conflicts and violence. While most of the existing international security architecture emerged after the Second World War, the nature of conflicts has substantially changed in the past seven decades. Although states waging wars have declined, non-state actors such as militias, terrorist organisations, and crime syndicates as belligerents have been widely recognised (United Nations n.d.). Technological advances have shown that they have the potential to enable biological attacks by overcoming the barriers of acquiring bioweapons (van Aken & Hammond, 2003). This threat has grown mainly due to the expansion of biotechnology, with more access to new ways of developing and producing toxic substances and the biological agents used to attack humans, livestock and crops.

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One such biological agent is *Bacillus antracis*, naturally found in tropical environments and causes anthrax, an infectious disease that generally affects animals. The disease can affect humans if they encounter infected animals or animal products. The *Bacillus antracis* is a potential bioweapon that can enter humans through water, air, or food (Centers for Disease Control and Prevention, 2022). Its features, such as the wide availability of the pathogen, its ability to be produced in labs, and its high morbidity, make it an eminently suitable bioweapon, as witnessed by its historical use (Santana, 2019). While bioterrorist attacks such as anthrax are a looming threat, ensuring biosecurity requires the interplay between science and security. Science diplomacy can be an important policy instrument for reducing the threat of direct and indirect conflicts. Multilateral and international organisations are central in enabling a platform for such discussions and actions. The G20, a forum of the world's largest economies and technologically advanced states could significantly address this challenge. The platform provided by G20 can help its members leveraging resources and expertise collectively and work towards shaping the global agenda for addressing the challenges posed by biological- or bioweapons.

Bioweapons: A Need for Discussion

The Securitisation theory provides much help to define this threat from a theoretical perspective. The Securitisation Theory is a constructivist approach that examines why and how specific issues are viewed as security threats (Floyd, 2011). The securitisation process is often defined as an active approach by an actor in charge of securitising; for example, the government addresses the issue to overcome an existential threat to a particular group, critical infrastructure, or object. The use of resources for enhancing the emergency response in such situations is justified (Oelsner, 2005). One of the ways to apply this lens to explain states' response to the threat of bioweapons is by analysing if securitisation will overcome the existential threat, and the protection of a particular object will promote human well-being and finally, if the response is measured appropriately to a particular threat in question. Accordingly, the threat of bioweapons is framed as a security threat, as their widespread use threatens both humans and the environment. Furthermore, securitising this threat allows decision-makers to adopt and implement appropriate policies and utilise resources.

The United Nations Office for Disarmament Affairs (UNODA) defines bioweapons as the use of biological agents in war to cause harm to man, animal or plants (UNODA n.d.). The effects of such weapons are multifaceted and protracted, causing innumerable losses to humans (Health aspects of chemical and biological weapons: report of a WHO group of consultants 1970). The capability of causing indiscriminate and profound trauma and irreversible environmental damage has led bioweapons to be categorised as one of three Weapons of Mass Destruction (WMD). Although there is considerable moral antipathy towards acts of deliberately spreading diseases, history provides multiple examples where biological weapons were used in war to gain an advantage. The Centre for Disease Control and Prevention (CDC) has identified a few biological agents which

Table 1: Biological Agents Used During Conflicts

The instance of agent being used	Disease	Pathogen
Virus		
Eighteenth-century N.America	Smallpox	Variola major
Second World War	Encephalitis	Alphaviruses
Bacteria		
Fourteenth-century Europe	Plague	Yersinia pestis
First World War	Anthrax	Bacillus antracis
	Glanders	Burkholderia mallei
Second World War	Anthrax	Bacillus antracis
	Tularemia	Francisella tularensis
	Plague	Yersinia pestis
	Cholera	Vibrio cholerae
	Food poisoning	Salmonella,Shigella
	Glanders	Burkholderia mallei
	Typhus	Rickettsia prowazekii
	Various toxic syndromes	Various bacteria
Soviet Union,1979	Anthrax	Bacillus antracis
USA,1990s	Food poisoning	Salmonella,Shigella
Japan,1995	Anthrax	Bacillus antracis
USA,2001	Anthrax	Bacillus antracis

Source: CDC

could most likely be used for a bioterrorist attack. Table 1 provides a list of several biological agents employed in various conflicts (CDC, 2018).

One commonly cited example is the distribution of blankets infected with smallpox to the American Indians by the British during the French-Indian War (Alibek, 2004). In recent history, the use of biological weapons against animals and chemical weapons on the battlefield has been widely observed despite the ban on using asphyxiating or deleterious gases by the 1899 Hague Declaration (International Humanitarian Law Databases n.d.). This led to the 1925 Geneva Protocol, which reaffirmed the ban on chemical weapons, and added a prohibition on using bacteriological weapons in warfare (UNODA n.d.). Despite such laws and conventions in place, most of the warring parties in World War II indulged in developing bioweapons. The United States, Britain and Canada were found to be working closely due to the fear of German attack (Stockholm International Peace Research Institute 1971).

Japan, not a signatory of the 1925 Protocol, was said to have the most extensive program on bioweapons during the war. It was accused of undertaking field experiments of its offensive program on the prisoners of war in at least 10 Chinese cities (Frischknecht, 2003). However, the continued research and development in the post-war period called for a ban on biological or bacteriological weapons. The era witnessed considerable efforts for disarmament through institutional and declaratory approaches (United Nations ,1971). Thus, to curb the growing threat of such weapons, the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and their Destruction was adopted by the United Nations General Assembly on December 16, 1971, after discussions and negotiations in the UN's disarmament forum (Tuzmukhamedov, 2021). After entering into force in 1975, 183 states have signed and ratified the treaty, while Egypt, Haiti, Somalia, and Syria are non-signatories. Around ten states have neither signed nor ratified the Treaty (Davenport, 2022).

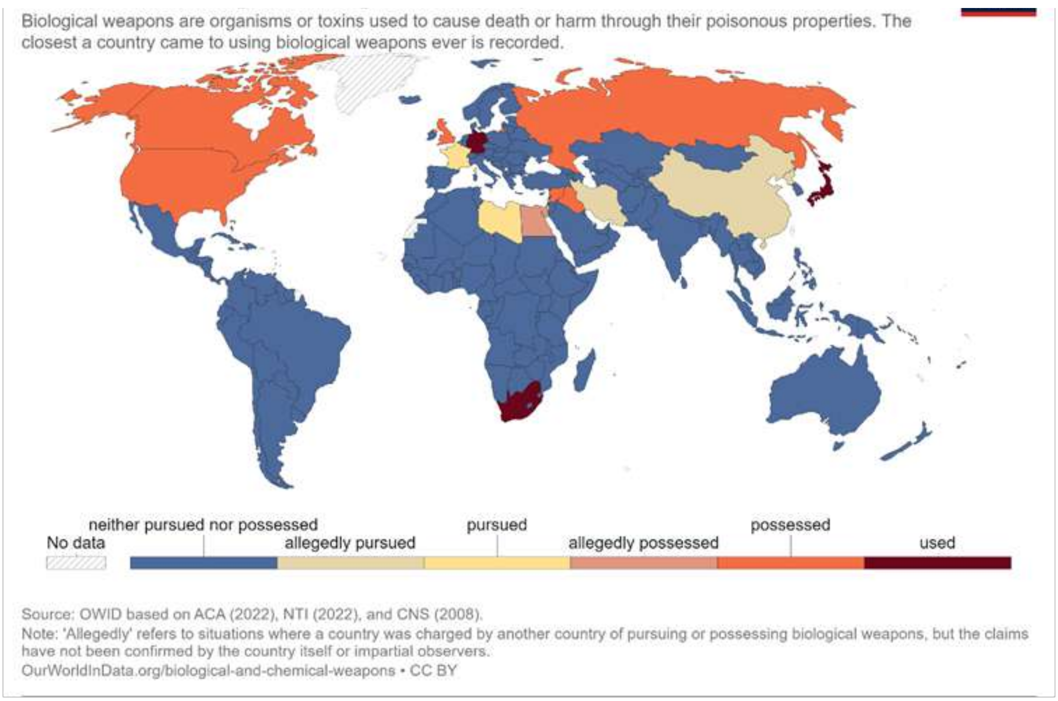
A complementary to the existing 1925 Geneva Protocol, the convention's main objective is to prevent the use of chemical and biological agents as weapons. While it prohibits acquiring and stockpiling such bacteriological agents, it permits their acquisition for peaceful and protective purposes. Such purposes include medical and sanitary-related activities, allowing for the development and production of antidotes and vaccines (International Humanitarian Law Databases n.d.). Further, the convention deems its success only when each signatory, by their constitutional process, takes necessary measures for the prohibition and prevention within territories under its control, as explained in Article IV of the convention (International Humanitarian Law Databases n.d.).

One of the shortcomings of the BWTC is that unlike the regimes governing chemical or nuclear weapons, it does not have an international organisation or institutional structure to verify compliance and ensure implementation (Beard, 2007). The Cold War politics along with the notion of obstacles for verification resulted in the lack of enforcement mechanisms which have proven to undermine the ability of the Convention (Guillemin, 2005). In the 1990s, in the Third Review Conference, the VEREX, an expert group, was established with a mandate to identify and examine verification measures. Over a span of four meetings, the VEREX had recommended 21 measures which led to the creation of Ad Hoc Group in 1994 to negotiate and prepare the BWC draft facilitating the creation of an international organisation and a standard verification system (Ad Hoc Group of Governmental Experts and Tóth 1993). Despite rejecting the draft by the Ad Hoc Group in 2001, the US has reconsidered its position on the verification process. The recent meetings have led to the creation of a working group to strengthen the Convention's ability to address concerns about verification and compliance (U. S. Mission Geneva and Jenkins, 2021; Cropper et al., 2023).

The development in the field of biotechnology has raised questions about the existing understanding of the field and its applications. The emergence of newer capabilities and services has prompted questions about exploitation for creating harmful pathogens. These developments have raised questions such as measures to differentiate efforts from peaceful initiatives by identifying advances and applications from a perspective of threat. While the developments have led to discussions including in BWC, there is a lack of a definitive approach and mechanisms that could address the new concerns about ensuring the peaceful advancement and application of biotechnology.

These conventions were adopted during the 20th century, primarily due to the concern of states using bioweapons. However, in the 21st century, the threat is mainly concerned with the possibility of rogue states and violent non-state actors employing these weapons to further their goals. Figure 1 paints a grim picture of the involvement and the instance of the use of biological weapons (Herre and Roser, 2022). Interestingly, we see that some of the G20 countries were involved or have been accused of pursuing such attacks historically. Thus, there is a need for G20

Figure 1: Historical Biological Weapons Activity



Source: Our World Data

as a platform to learn from the past and reconsider the new emerging threats from bioweapons collectively.

One of the emerging threats is bioterrorism, which refers to the use of bioweapons by groups or individuals to promote a particular religious, social or political agenda by primarily targeting civilians. Agents with specific impacts on humans, including viruses, bacteria, and toxins such as anthrax and smallpox, are used to cause widespread panic and loss of human lives. Aiding this threat is the evolution of biotechnology and the emergence of new scientific methods that can be employed to alter the genes of a particular organism. In its broadest sense, the field of genetic engineering refers to the involvement of humans in transferring genes among biological organisms in an artificial setup. Research on simulating and redesigning genetics has become routine in the internet era, with several articles published worldwide (Jefferson, Lentzos, & Marris, 2014). While this is a welcome move regarding knowledge sharing, these could be used for genetic manipulations in the context of bioterrorism or biological warfare by creating mutations with harmful properties such as increased survival and drug resistance. The situation increases the threat of new-generation weapons with unpredictable effects and positions.

Additionally, the continuous development in the biotechnology field has made it possible for biological factors to be developed in a lab environment (Fraser & Dando, 2001). Thus, with a mix of classic biowarfare agents with new technology, the spread of terrorist attacks using such organisms cannot be ignored. Hence, reiterating the need to recognise and prepare the populations to face global biological threats.

In the 1984 Wasco County (The Dalles, Oregon, US) incident, more than 700 people were affected by food poisoning. The investigations revealed that a group of followers of Rajneesh (Osho) had deliberately contaminated salad bars with *Salmonella enterica Typhimurium*. It was done with anticipation of incapacitating the voting population to favour the cult's candidates in the 1984 Wasco County elections (Nova Online, 2002). The 2001 Anthrax attack in the United States, where letters containing *Bacillus anthracis*, the bacterium which causes anthrax, appeared in the US mail. It was found that at least 22 people were affected due to anthrax, of which five died. Additionally, a substantial economic cost was incurred due to the decontamination of the post offices and other government buildings. The attacks, however, led the medical communities to develop effective countermeasures against biological agents (Federal Bureau of Investigation, 2016). The threat of bioweapons was one of the key issues taken up under the Obama Administration, wherein international cooperation in biosecurity was sought to reduce naturally and deliberately fostered outbreaks (Koblentz, 2012).

Another example is from Japan, where Aum Shinrikyo, a religious movement and cult, firmly believed that chemical and biological weapons were two means to attain their goal of establishing a new Japanese government. While the sect successfully used chemical weapons twice, it used Sarin gas in Matsumoto City (1994) and the Tokyo Subway System (1995); however, their attempt to develop a widescale bioweapon using *Bacillus anthracis* (Tu, 2014).

Despite not being used widely, these instances are often seen as a reference point for decision-makers to take concern about a bioterrorist attack. Compared to other WMDs, the nature of such attacks is difficult to identify as there are no dramatic signals such as blasts and destructions. The attacks can only become evident when there is a pattern of suspicious cases involving viruses or bacteria. However, even a successful pattern identification might not help identify perpetrators. This is mainly due to the time gap between the release of biological agents and the surfacing of cases with similar patterns. Recognising the sources of attack might become even more complex if it is designed to occur as a natural phenomenon and not a premeditated attack. Thus, plausible deniability is one of the main reasons behind the looming bioterrorist attacks.

Science Diplomacy and Bioweapons

While the military and police are generally responsible for countering the threat of terrorism, in case of a bioterrorism attack, the role of the public health system becomes crucial in the prevention, response and recovery making it a multisectoral issue. Safeguarding public health is one of the foremost necessities. However, this issue remerges only when major pandemics like virus outbreaks exist. Although there are no clear answers about the origins of the COVID-19 virus, multiple states across the globe handled its outbreak as a security issue. One of the key takeaways from the pandemic is that it highlighted the need for robust scientific collaborations and networks that can enable preparedness for future crises.

The onset of the COVID-19 Pandemic, led the WHO to be at the centre of affairs concerning updating information about the virus, investigating its origins, and calling for public health measures. The ambiguity surrounding the origins of the coronavirus also led to the question of the ability of the BWC to play a critical role in addressing and preventing the threat of deliberate biological attacks, which if not contained in a timely manner could pose the threat of a pandemic. COVID-19 could be used as a catalyst to revisit the overlapping interests within the BWC, WHO and the International Health Regulations (IHR). The IHR plays a crucial role in requiring all states to detect assess and report public health concerns to respond appropriately, while the BWC aims to eliminate the threat of biological agents being used as weapons. The dependence on governments for disease surveillance and formulating effective countermeasures forms a formidable converging point for these international mechanisms to enhance their ability to mitigate future threats of deliberate bioweapon usage as well as pandemics. In this regard, sharing scientific information, as seen during COVID-19, is critical as it helps prepare and direct guidance to the healthcare workforce, policymakers, and the public.

Unlike the Chemical Weapons Convention, the BWC lacks capacity to respond in case of a significant biological attack, a shortfall that can be addressed in collaboration with IHR, especially when the negotiations for the Pandemic Prevention, Preparedness and Response Instrument are in process The pandemic has shown that no states are safe or immune, and hence the situation should be used to deliberate on issues which were deemed to be difficult previously. The PPPR Instrument due to be finalized in 2024 could bring synergy between the IHR and BWC rules and regulations to enhance the capacity to address issues related to information giving, policy, guidance and surveillance while working towards curbing the threat of bioweapons (WHO, 2023; Gerstein, 2021).

An effective intervention can be formulated with transparent and accountable science policies and data for evidence-based decision-making. Science diplomats are among those who could help increase openness at the international level. Another issue that was at the centre was the role of international or global organisations, such as the WHO. Although the organisation was questioned about some of its moves, the crisis called for international cooperation, especially in healthcare. The national laws governing public health emergencies must incorporate biosafety and biosecurity measures in accordance with the existing international laws and norms. Multilateral forums like the G20 can step up to encourage its members to interact and coordinate biosecurity research. Thus, coordination among public health facilities, law enforcement, the private sector, and the international community with biosecurity and bioscience researchers is vital for strengthening security against biological threats.

The threat of bioterrorism needs to be approached not just as a security concern but also from the realm of public health including One Health. While both are equally essential components, delays in identifying such diseases could have impacts at the international level. This has been highlighted, most recently, during COVID-19, highlighted an essential linkage between public health and foreign policy. Hence, a comprehensive approach to foreign policy and international cooperation is required. One of the possible ways to achieve stable cooperation is by enhancing the responsiveness of health systems to identify unusual patterns of illness and diseases. Strong connections between national and international health systems also play a vital role by enabling information dissemination bidirectionally. The national security architecture, including intelligence agencies, also plays an essential role in ensuring the timely transfer of information regarding suspicious outbreaks. International cooperation could help in timely surveillance and awareness of possible bioterrorist attacks and rapidly communicate the know-how to manage and prevent new outbreaks. It would also ensure an adequate supply of medicines, protective equipment, diagnostics, and vaccines to curb the further spread. The extension of military understanding to share databases of threatening bioagents and their possible sources could help build a comprehensive system to combat bioterrorism. Biological weapons and bioterrorism pose a multifaceted threat which demands tailored solutions.

While being critical for finding solutions for critical issues, the development in Science and Technology have created multiple challenges. In a time dominated by conflicts, climate change, misinformation, and obstacles to rules-based order, the need is for science and scientists to step into use of newer technologies while enhancing the existing knowledge to address these challenges. Since many challenges and obstacles transcend borders, there is a need for international collaborations between multiple stakeholders such as the governments, industries, NGOs, and academia. The science-policy interface can be an important tool to strengthen efficiency of the existing multilateral system, especially at a time when its ability to address new and emerging threats is being questioned.

The employment of the existing idea of track two dialogues among the scientific community across borders could help in reorienting the effective implementation of international treaties and conventions while helping in building the capacities of their own states. Academia and think tanks also play a critical role in making a connection between policy makers, diplomats and science through their research and dialogue engagements. On the political front, there is a need for collaboration of various ministries to view science beyond economic and technological advantage. Inclusion of scientific angle in foreign policy decision also is key with the security and national interests becoming more comprehensive, and with issues of climate change, biodiversity loss, and regulations of global commons which are difficult to manage within political boundaries and have geopolitical consequences. Hence, it becomes imperative to include scientific and technological views in societal and diplomatic missions.

The advancement in biological and genetic engineering has proved beneficial due to its use in human health including the production of antibiotics and, antiviral drugs, new vaccines, which in turn has boosted the enhancement of human immunity. On the contrary, this also has increased the threat of bioterrorism due to advancements such as the ability to enhance lethality of pathogens or specific genomes within them to targets (Cooper 2006). The same development has also led to the option of creating counter-weapons in case of an attack. However, like nuclear weapons, these weapons could be highly lethal. Thus, diplomacy is one avenue which can lead to better preparedness, detection, prevention, and solving of the challenges posed by these WMDs.

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ARTICLE

G20 as a Rare Earths Bazaar: An Opportunity for the Indian "Empire"

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Introduction

The decline of the unipolar order along with an explosion in the complexity of global supply chains has resulted in the rise of "empires", which are principal actors in global politics today. These empires interact, cooperate, compete and shape the behaviour of other empires and countries by waging economic warfare in a globalised world, where supply chain control is the medium of transmission as well as the weapon of choice. Thus, supply chains are both determinants and consequences of geopolitical moves made by empires. Supply chains are weaponisable instruments of foreign policy, while their choke points are also fragile vulnerabilities for any modern economy. Science diplomacy, thus, becomes both an exercise for countries to acquire relative advantages by improving their standing within specific supply chains, as also to ameliorate broader supply chain constraints on a multilateral or even a global scale. Thus, science diplomacy becomes an exercise in reducing vulnerabilities, enhancing strengths, and addressing broader social, economic, or scientific concerns over the many supply chains which underlie a nation's prospects. In such a context, the G20 emerges as an ideal forum to modulate global supply chain governance, owing to its composition, modality of engagement, and potential to resolve critical informational asymmetries which induce fragility. This proposed role for the G20 is not a departure but merely an extension of its already existing operation as a systemic hub for global governance. Finally, the ideas developed in this

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paper are applied to rare earths, a critical requirement for the modern world, and the possibility of the G20 as a "rare earths bazaar" having a stabilising influence on global supply chains is discussed. Rare earth supply chains have multiple points of fragility present in them, they are prone to disruptive price fluctuations, and they present a high likelihood of globally damaging weaponisation by currently dominant empires. The G20 we feel can host a platform that leads to institutional mechanisms to ameliorate and buffer these key issues. India is presented as a linchpin in its potential efforts, being an empire which is steadily increasing its power across supply chains.

Empires

The word "empire" carries a far more impressive connotation than the term "nation-state". In the context of this paper, an empire has the following characteristics, each of which is necessary and the three taken together are sufficient:

1. The absolute condition: An empire exercises control over an economy (or many economies) and this makes it a master of multiple critical supply chains, especially those with a technological element, i.e., an empire has the capability and capacity to exercise *strategic autonomy* (Saran, 2018);
2. The relative condition: An empire possesses sufficient heft and willingness to force other empires or nation-states to contend with, react, alter, or adjust fundamental aspects of their own economic, foreign, or military policies, i.e., empires have the *capability as well as the willingness to project power* (Joshi, 2017), and
3. The constitutional condition: An empire has a *civilizational core* at its centre, and this core serves as the source of all ontology (Dugin, 2022), while being clothed in institutional paraphernalia; an empire exercises control over its peripheries be they vassals, dependencies, or tributaries.

Implicit in the relative condition stated above is the fact that an empire seeks a sphere of influence outside its immediate political domain—a vijigishu (one desirous of victory) at the cynosure of a mandala (circles of States) (Kautilya, 2000). While international law holds states to be equal by definition, the equality of states as affected by common usage is really their inequality or status (Dickinson, 1920). The most unequally powerful, in terms of state capacity, power projection, and the willingness to engage in projecting their power as an inherent element of foreign policy, are empires. The foregoing definition would allow America, China, India and Russia to be considered empires, and would exclude middling powers (Martinez-Alier, 2022).

The modern world may thus be currently defined as a chessboard of four empires having the following central entities: the U.S.A., China, Russia, and India. While the situation is definitely evolving, the relative strength (supply chain and otherwise), existence of a civilizational substrate to their nations, and significant international influence of these empires makes it unlikely that this quartet will undergo any changes in the short to medium term. This approach is replicated almost exactly in Russia's 2023 Foreign Policy Concept document, whereby Russia, China, India, and the U.S.A. are identified as "sovereign centres of global power and development": a vindication of the foregoing analysis (Presidential Executive Office of Russia, 2023). In the supply chain context, the four empires of the modern world might look at their supply chains as being either extrinsic or intrinsic, the former involving other empires and the latter limited to their local domains of influence. These empires would then strategise accordingly.

Being an empire in a competitive world implies that the central State within an empire has crossed a certain threshold of power, not only just in terms of hard power, but also economic, i.e., over supply chains. There occurs a qualitative shift in an empire's conduct of international relations, whereby competition and collaboration take place simultaneously with other empires. These inter-empire interactions are governed by the complicated calculus within and outside of each empire's mandala, driven by cost-benefit matrices which juxtapose an empire's own interests with escalation ladders against other empires' actions. This conceptual mechanism of inter-empire interaction operates on all levels, whether it is military posturing or the projection of 'soft' power, such as cultural diplomacy. Science plays a prime role in the formulation of the aforementioned matrices, with science diplomacy having to undergo an evolution to better cater to this role.

In terms of the three classical dimensions of science diplomacy, (The Royal Society & American Association for the Advancement of Science, 2010) the dawn of a multipolar world characterized by empires necessarily places science diplomacy within a new context.

1. Science in Diplomacy: refers to giving and taking scientific advice, the scientific community informing diplomacy, scientists facilitating negotiations, and capacity building. In an empire-driven paradigm, the involvement of scientists in the diplomatic process will necessarily be shaped by diplomatic priorities of the empires. Thus, sectors which are identified by an empire as having strategic significance may cause scientific inputs to be both more readily invited as well as the scope for such advice to be somewhat limited to the achievement of goals which are fundamentally political and economic in nature. The scientific inputs going into the formulation of the foregoing cost-benefit matrices driving diplomacy will thus be viewed with a far more functionalist, utilitarian, and even political perspective going forward, as seems to be the post-Covid trend.
2. Diplomacy for Science: refers to developing relationships in scientific areas where scientists may require diplomatic assistance to work together. The contours of collaboration and competition between the empires are at their most basic, political decisions made to serve geopolitical and economic goals. Even issues which are of a global nature and were once open to a greater degree of consensus, such as climate change or disease prevention, have been undergoing steady politicisation, leading to a far more minimalist consensus. Thus, the provision of diplomacy for science will again be subject to the aforementioned cost-benefit matrices. International scientific cooperation, thus, may become further selective based on the perceived priorities of an empire.
3. Science for Diplomacy: refers to scientific cooperation to improve international relations between countries. With regards to this particular pillar of science diplomacy, the economic, political, and technological necessities of competition between empires may foster further cooperation between individual countries or groupings. A country possessing scientific or technological expertise in a niche which corresponds to an empire's

priority will necessarily lead to the possibility of wider diplomatic arrangement. In this paper too, for example, the distribution of rare earth reserves as well as related science forms a confluence with the priorities of empires, giving rise to hitherto underexplored vistas of diplomatic cooperation.

That said, the world's empire-driven calculus within a realist paradigm in international politics means the lines between science and politics will necessarily blur. Science is the bedrock for superior decision-making, competitive advantages, and strategic superiority, which makes science an important political subject for any empire. Scientific priorities and the overall approach to science diplomacy would therefore be subservient to priorities derived from a political process, i.e., cost-benefit matrices.

1945: Origins

The genesis of the modern empire lies in the dissolution of its earlier iteration, the colonial empire. Colonialism entailed a careful strategy of deindustrialisation, policy bottlenecks, and extractive economics to engineer underdevelopment and the crippling of economies (Robinson & Acemoglu, 2013). Even as supply chains matured, lengthened, and proliferated in the West, the East descended into a squalor which supplied captive commodities and forcefully extracted manpower—a drain of wealth (Naoroji, 1902). The colonial method itself was an outcome of a politico-economic process, as the world's supply chains were moving from simple to complex. Production processes were globalising as the geographic range of power projection increased through technological innovation, and vice versa. Let us take sugar as an example: sugarcane was grown in the Caribbean, using labour enslaved in Africa, and financed using precious metals mined in South America. Finance, logistics, and military technologies all advanced and globalised symbiotically.

Post WW2, colonialism reached its limits with the efflorescence of national consciousness in erstwhile colonies, and devastated European post-war economies requiring a policy shift (Watts, 2011). The number of new countries increased greatly, and no country could be ignored while optimising one's supply chains. Establishing control over supply chains afresh begat a new modality for old empires: Domination through hot means (naval might, land armies, direct political control) yielded ground to imposing bondage in cold places (economic and financial strangulation, global institutions, mercenaries, and subversive political control) (Malmgren, 2021). The modern world is the culmination of this multifaceted evolutionary process.

The concerns of the Cold War era, which included, inter alia, arms control, nuclear non-proliferation, food security, and development, led to recognition of science's role in diplomacy, and saw the setting up of a number of institutions such as the International Institute for Applied Systems Analysis, and the International Atomic Energy Agency. The overarching purpose for these efforts was "to link scientists from East and West, from developed and developing countries, in an effort to maintain some degree of global connectivity even in the face of great power tensions". (Turekian, 2018) The collapse of the Soviet Union in 1991 fundamentally altered global politics, and a unipolar era marked by the dominance of the Amerisphere commenced. Here, the use of American science diplomacy was principally to better link countries and scientists to "international research priorities" (Turekian, 2018), which were effectively American priorities. Science Diplomacy efforts were formalised in a framework with the report entitled 'New Frontiers in Science Diplomacy' (The Royal Society & American Association for the Advancement of Science, 2010); the same time saw American international priorities, such as engagement with Middle Eastern countries, having a science diplomacy content. With multipolarity becoming the new normal, science diplomacy needs to evolve an alternative modus operandi to adapt itself to changed realities, with the proposal in this paper of the G20 as a rare earths bazaar being a possible template to pursue.

1945-2008: Amerisphere and 1991 as a major Inflection Point

The period 1945-2008 signifies the zenith of the American empire. America successfully amalgamated economic prowess and military might to build a global governance architecture (Louw, 2010). Thus was laid the foundation of a new global empire where global finance, international institutions, localised proxy wars, and political meddling were prime. The Bipolar structure of world affairs established after 1945 saw the U.S.S.R compete with the U.S.A. on multiple metrics, including science and technology. Yet it was mostly a game of constant catching-up for a statist U.S.S.R. with the U.S.A. being a leader, as exemplified by the ultimate failure of the Soviet semiconductors program. (Chi, 2015) After the disintegration of the U.S.S.R. in 1991, which was in and of itself an inflection point for both global politics and science diplomacy, the world became 'monopolar' or 'hegemonic' (Daalder & Lindsay, 2003), and the world collapsed into a single unit surrounding the American nucleus. This was achieved not just with brute militarism, but careful control over global supply chains, international institutions, and soft power including social media. The sum total of these institutions along with the phenomena they brought about is what can loosely be termed as 'globalisation' (Nye, 2002). The concomitant proliferation of global supply chains underwritten by American power, combined with unchallenged American soft power, resulted in the world being "flattened" (Friedman, 2007, p.7).

The American empire, or 'Amerisphere', is structured like a mandala. At the empire's heart is the U.S.A. itself, favoured by geography with its two ocean moats. It is then surrounded by closely dependent States with little strategic autonomy: Japan, Germany, and the U.K. Then come military alliance structures such as NATO, followed by a patchwork of economic deals (such as Free Trade Agreements and trading blocs). Beyond these were think tanks (Atlantic Council, Hudson Institute, Trilateral Commission) and further beyond were informal relationships, investments, and subterfuge. American power was inescapable in the 1990s: the global financial system, global public infrastructure, the dominance of the U.S. Dollar, the World Trade Organisation, lines of communication, and essential supply chains were in American hands, directly or by proxy.

2008: Another Inflection Point

The 2008 global financial crisis was another inflection point for the world. Underpinning the global economy is financialisation, a methodology in which financial instruments mediate the allocation of capital to entities and people. 2008 saw the entire system unravel, with intricate webs of financial relationships falling into (inevitable) auto-cannibalistic feedback loops, portending economic meltdown. Many fault lines converged into the global financial crisis and compounded it. These fault lines remain unaddressed, primarily due to entrenched interests (Rajan, 2011).

Come 2008, by virtue of China being intrinsically enmeshed in the global system (especially after China's entry into the World Trade Organisation in 2001), its control over global supply chains gave it outsized power (Wroughton, 2018). The consequent shrinking of the American empire has not been stemmed; in our view, the U.S.A. by 2035 would become just one amongst many empires, losing its exclusive hold over the world's commanding heights. The ongoing de-dollarisation of the global economy is just one example of the fracturing of globalisation, and shrinking American power (Pozsar, 2022a; Pozsar 2022c).

The world, therefore, is currently in a time of transition. The result is that the world is currently operating in a VUCA state. Originally framed by the U.S.A. Army War College to describe the post-Cold War world, the acronym VUCA has been rapidly adapted by business strategists operating in a fluxional commercial environment (U.S. Army War College, 2022). VUCA as a useful analytical perspective within international relations has been gaining currency, especially in terms of viewing contemporary conflict (Alaraby, 2020) and institutional resilience (Korosteleva and Petrova, 2021). The VUCA framework permits a better description of the nature of global dynamics in an empire-driven paradigm, mediated by competition and collaboration coexisting. The acronym stands for:

1. Volatility: unexpected, unstable challenges which may be of unknown duration, but not necessarily hard to understand;
2. Uncertainty: the basic phenomenon's causes and effects are known, but surrounding information like timing, triggers, intensity, and changes are not well understood;
3. Complexity: the situation has many interconnected variables and nuances, where the volume or nature of the interplay between these factors is overwhelming to process;
4. Ambiguity: even basic causal relationships are unclear, and the circumstances are marked by the existence of 'unknown unknowns' (Bennett & Lemoine, 2014).

The relative decline of American power has resulted in a reversion to a somewhat Hobbesian, neo-realist mean, characterised by cut-throat competition (Walt, 2022). The actions of empires, as well as other nation-states, are mostly recalibrations towards these changed realities. The modality for this ensuing competition is spread across an omnipresent network of global supply chains. It is thus convenient to analyse supply chain issues in today's changing world as a continuing trapeze between four major players: the U.S.A.; China; India; and Russia.

1. The U.S.A. is a power in decline, overseeing a fragmenting global institutional architecture. It intends to maintain an edge by exerting financial and technological control over supply chains.
   a. While Europe has been making attempts at garnering a modicum of strategic autonomy from the United States, its internal contradictions, dependence on the United States, and economic limitations vis-à-vis China and Russia presently render the process nugatory (Budryk, 2020).
   b. Meanwhile, many countries within the Amerisphere, such

as South Korea, Australia, and France, have been able to exercise greater autonomy, as America's hold decays (The Korea Times, 2022; Rascouet, 2023).

2. The fallout of the 2008 crisis allowed countries to recognise that the real economy was central. It was actually irreplaceable. This realisation was key to the renewed audacity of China and Russia. A union of manufacturing and commodities, as opposed to finance, was taken up as a different and arguably better model for the global economy (Bonner & Smith, 2022; Pozsar, 2022a; Pozsar 2022b).
3. On one end is a finance-led, market-mediated political economy with stress on services, exemplified by the West. At the other end is a State-driven commodity and labour-led substitute (Pozsar, 2022b). This approach focuses on manufacturing and is being pushed by China and Russia (Martyanov, 2021). India is an oddball, with elements from both systems along with a unique intrinsic paradigm.

All players, empires or otherwise, are players in the supply chain tumult, subject to both fragility and weaponisation. For science diplomacy, this takes us back to the inevitable politicisation of, and subjection to political constraints for, science diplomacy. Thus, well-established and insulated spheres of cooperation such as space are witnessing a return to competition, with climate change efforts also facing similar political pressures. Similarly, the fallout of the COVID-19 pandemic saw both the rise of new science diplomacy efforts such as India's 'vaccine diplomacy', as also the atrophying of other kinds of cooperation, such as virological and immunological cooperation between China and the U.S.A. Overall, science diplomacy will reflect the cost-benefit matrices of countries, and their respective interactions.

Supply Chains

Empires are the proper units of analysis in this paper due to empires' concentration of control over global supply chains, for example, pervasive American control over the semiconductors supply chain (Khan et al., 2021). Therefore, by controlling the supply chains of critical industries or global infrastructure, empires practise, profess, and propagate their foreign policy interests. These foreign policy interests, which are ultimately derived from a political enunciation of national interests, are materialised through the exercise of diplomacy. Likewise, supply chain dynamics impact the comprehensive national power of a country or alter the ability of an empire to project power, which necessitates, inter alia, foreign policy responses (Solingen, 2021). Power, power projection, and supply chain power or control are mutually interacting, even overlapping, phenomena existing in a continuum.

Simply stated, "a global supply chain is a network between an organisation and its suppliers and consumers that incorporates all the transactions in transforming raw goods into marketable products. Global supply chain networks include the activities, people, technology, information and resources." (Bailey, 2022). A VUCA world necessitates countries to secure supplies of critical inputs for key industrial sectors. As goods, products, and processes become progressively complex with respect to logistics, capabilities and processing, each node in the supply chain is a potentially exploitable point of vulnerability. At times there is cooperation, but mostly the global economic network tends to chaotic competition (Chen & Peng, 2020). Countries compete for limited flows at these choke points. Each country strives to reduce its dependence on unreliable or vulnerable choke points, and enters into commercial compromises as and when needed.

With respect to science diplomacy, each of the three classical pillars spelt out above has a role to play for countries to manage their supply chains. Science in Diplomacy allows for effective identification of risks, opportunities, and potential sectoral strategies. Diplomacy for science enables scientists to understand political priorities, gain access to institutions, and tailor their advice accordingly. Science for diplomacy. Science for diplomacy enables countries to establish mutually beneficial supply chain linkages which lead to a reduction in supply chain vulnerabilities for both (i.e. increased supply chain resilience). The three pillars, it is worth noting, are not distinct silos but are concepts which, inter se, engage in a constant flow of data and concomitant adjustment.

The nature of warfare in a world characterised by highly complicated supply chains is primarily economic, rather than overtly military (Lopez & Cortright, 1995). Thus, the theatres of warfare are in 'cold places' such as cyberspace, space, the psychological domain, the informational domain, and deep waters, even though wars being waged are 'hot' which involve the flow of technologies, goods, and commodities (Malmgren, 2021). The decline of globalisation itself is the result of an economic war being carried out by and amongst the four empires, characterised by low trust and a scramble over supply chains.

Modern supply chains, being complicated phenomena, have two essential attributes which turn them into both channels and domains of (economic) warfare: fragility and weaponisation.

Fragility

By the term fragile, one does not only mean prone to breakdowns due to vulnerabilities, but a general sense of being uncomfortable with volatility. According to Nassim Nicholas Taleb, "the fragile is what is hurt a lot more by extreme events than by a succession of intermediate ones." (Taleb, 2012, p.277). The twilight years of Western hegemony, the resulting atrophying of the West-imposed order, and an uncertain China which cannot adequately fill the West's shoes as the global policeman, have unleashed cut-throat competition amongst all players. In such a reversion to a condition where the world order is fluid and anarchic without mutual trust, fragility seeps into supply chains. Therefore, the focus shifts from efficiency, which inherently inures with fragility, to resilience, which is antifragile.

Major companies are waking up to the importance of supply chain resilience (just-in-case thinking as opposed to just-in-time thinking) after the terrible onslaught of the coronavirus (Chief Economic Advisor to the Government of India, 2023). The ability of the entire chain to withstand disruptions and limit deleterious effects has become paramount: the chain must resist pressures, stabilise itself, and recover; it must transit from a complicated system to a complex one (Nason, 2017). A resilient supply chain organically adapts to sudden changes and unexpected risks that can disturb established patterns (Boggess, 2023). Unsurprisingly, India's External Affairs Minister, S. Jaishankar, has also flagged supply chain disruptions as a "key challenge facing the world" (Press Trust of India, 2023).

The same line of thought is reflected by policymakers worldwide. The U.S.A.

has explicitly focused on supply chains as a core strategic issue going beyond economics or defence (Office of the President of the United States of America, 2021). It is consciously attempting to maintain its technological edge vis-à-vis the world and re-industrialize, bringing large parts of the supply chain within its grasp (Moser & Kelley, 2022). China has doubled down on its Made in China 2025 initiatives, in accordance with the Dual Circulation Strategy to insulate itself from global volatility (Paterson, 2022). Similarly, India has unveiled a slew of defence indigenisation projects, an ambitious National Logistics Policy, and flagship Production Linked Incentive (PLI) schemes to cut down India's dependence on imports in key sectors while positioning India as a player in global supply chains (Ministry of Commerce and Industry, Government of India, 2023).

All of the above initiatives, apart from physically onshoring stretches of critical supply chains and developing domestic intellectual property, are also geared to insulate supply chains from disruption caused by what the authors call innovation shocks. The Soviet experience shows that credible innovators shape the trajectory of technological platforms that become essential in a supply chain, and innovation can become a cause of disruption in and of itself (Chi, 2015). Coping with innovation shocks requires reallocation of time and capital from other endeavours, causing systemic stress. Developing and maintaining a domestic scientific-industrial base for critical supply chains can ameliorate weaponised innovation shocks arising from outside. At the same time, the possibility of originating and assimilating domestic innovation can not only increase a country's supply chain power, but deliver an innovation shock to others, appropriately weaponised through effective science diplomacy.

Weaponisation

Weaponisation of supply chains is a corollary of fragility. Countries compete with each other; they will seek strength, and they will strike at their enemies' weakest points.

Interconnectedness and the global scale of supply chains mean that a bilateral disruption can snowball into a global one. Tensions around the Taiwan straits, for example, have resulted in a global fallout as most semiconductors are fabricated by Taiwan based TSMC. China is donning a militaristic posture because American sanctions can choke China from accessing leading-edge semiconductors. The U.S.A., in turn, is taking measures to prevent China from acquiring sensitive technological capabilities that could whittle America's technological edge. As a result, players like India, Japan, Europe and the U.S.A. are actively offering incentives to companies that are looking to escape a geopolitical hotspot (Gupta & Gartner, Inc., 2023).

The Chinese strategy is relevant: the similitude of war and peace, in other words, the unity of the economic and military domains. Pronounced by Deng in 1978, the 'Sixteen Character Policy' is emblematic of Chinese thought (Bitzinger, 2009): "Combine the military and civil; Combine peace and war; Give priority to military products; Let the civil support the military". Resultantly, ranging from rare earths or electronics, China has successfully monopolised or dominated supply chains of foundational civilian, military, or dual-use technologies.

The treatise titled "Unrestricted Warfare" posited that war comprises not only troops and armaments but is fought over many domains: legal, cultural, economic, social, financial and psychological. The goal of warfare is stated thus:

> "...to use all means whatsoever—means that involve the force of arms and means that do not involve the force of arms, means that involve military power and means that do not involve military power, means that entail casualties and means that do not entail casualties—to force the enemy to serve one's own interests." (Liang & Xiangsui, 1999:56)

Forcing the enemy to serve one's own interests is well known in military science. Marshal Ivan Koniev stated it tersely in WW2: "We plan alone but we fulfil our plans together with the enemy, as it were, in accordance with his opposition." (Sevruk, 1969, p.27). The same idea is also at the heart of Valery Gerasimov's doctrine of "reflexive control" (Casparoglu, 2015). Unsurprisingly, when the U.S.A. decided to weaponise its currency and the SWIFT interbank messaging system against Russia, Russia gave tit-for-tat responses by limiting critical commodity supplies such as neon and titanium. Simultaneously, Russia's most dominant lender Sberbank has launched a Rupee account throughout its network in Russia and abroad, moving beyond the Yuan and Ruble (Fabrichnaya & Marrow, 2023). Building in redundancies, engaging in comprehensive supply chain-wide monitoring, and integrating antifragility as a critical metric for evaluating as well as designing supply chains are some essentials for having resilient supply chains which can withstand weaponised supply chain disruptions.

G20

The emerging multipolar order itself is "fuzzy" (Sadil et al., 2021), i.e., transitory and lacking certainty in what kind of equilibrium power dynamics will deliver. The G20, since its very inception following the 2008 global financial crisis, has fuzzy logic ingrained within its modus operandi. The G20 thus offers "the best crossover point between legitimacy (based on inclusiveness and representation), efficiency (which requires a compact executive decision making body), and effectiveness (where those who make the decisions have the greatest ability to implement or thwart them)." (Thakur & Cooper, 2012, p.147). Therefore, the G20 is an effective, all-spectrum response to a VUCA world characterised by fuzziness. It is a buffer against the economic vagaries of the modern world.

Even the composition of the G20 embodies fuzzy logic. There has been a criticism of the G20 as being based on arbitrary considerations; yet, critics forget that the G20's genesis was based on crisis-management, where it mounted an effective coordinated response to the Global Financial Crisis of 2008. (Central Bank of the Republic of Turkey,2015). An arbitrary grouping could not have established a successful counter to a system-wide crisis: the legitimacy of G20 lies in effective policy responses rather than ossified rules of membership.

Thus, the G20 is a still evolving entity which invites guest countries, and is open to inducting new members. Of particular importance is India's proposal to have the African Union join the G20 as a member, which would be a natural progression for the G20 considering its roles and initiatives. (Reuters, 2023) The G20 is not only a desirable compromise between legitimacy, efficiency, and legitimacy but also between the size of the organisation and its efficiency, where fuzzy logic allows for the timely and considered inclusion of new members.

With the lack of any institutional arrangement to reasonably negotiate, ameliorate, or reach gentlemen's agreements on supply chains, the G20 presents a germane forum for arriving at limited understandings in a fuzzy world as described above. As such, the G20 has certain unique characteristics which make it a well-suited mechanism to subserve the following essential global priorities:

1. Stabilising global supply chains under conditions of structural economic changes across the world;
2. Minimising supply chain disruptions by continuous dialogue and progressive inducements to commitments of a binding nature; and
3. Arriving at some agreed limitations on economic warfare as the balance of power pertaining to global supply chains is challenged and shifts Eastward.

G20 Composition: East + West

The composition of the G20 brings together a range of important players in global supply chains. The G20's open, unossified, and non-intrusive method of engagement provides a valuable global forum which brings together the East and the West, along with all empires, to prevent severe ruptures to global supply chains. In the words of Zoltan Pozsar:

> "The G20 is becoming the "G7 + Australia" = 8 countries on one side, and "BRICS + new applicants + the thematically aligned" = 11 countries on the other. 8 + 11 = 19. The remaining member, the European Union (EU), is perhaps the most directly affected by this global "split"." (Pozsar, 2022c).

Thus, even as the world polarises into rival camps, the doors for mutual arrangements remain open owing to the inclusive composition of the G20.

Likewise, the G20 is an intersection between multiple multilateral groupings such as BRICS, NATO, TPP, SCO etc. Naturally, the G20's omni-role engagement across members of these groupings extends a stabilising influence across the fault lines which exist amongst and between these groupings. The G20's externally stabilising nature also corresponds to flexible internal mechanisms which can prevent disagreements from derailing broader agendas. In particular, the ongoing conflict in Ukraine led to the emergence of the 'Bali Formula', whereby instead of issuing a uniform, singular Statement, there is a Chairman's Statement reflecting the agreed views of the G20, but with a few paragraphs reflecting the divergence of views. This has become standard practice during the 2023 Indian Presidency of the G20. These internal properties are not only standards worth emulating in other multilateral organisations, but are a contributing factor to the G20's amenability as a nucleus for the formation of global working consensuses. The forum will be of particular relevance in managing the ongoing shift of the world's economic centre of gravity eastwards; the BRICS countries have already overtaken G7 in terms of share of global GDP (Raghavan, 2023). G20 can therefore be the forum of choice for evolving terms of reference in stabilising global supply chains in the midst of profound, even disruptive, structural economic changes.

G20 Needs Basis Engagement: Portfolios of Interactions

The G20 emerged as a pragmatic response to the pervasive global financial crisis of 2008, with the express backing of the erstwhile G8 in its formation (Hufbauer et al., 2010). In addition, the shocks of the global war on terror, as well as the ongoing threat of climate change, had a scale with which pre-existing fora could not cope. All this is a direct outcome of globalisation, which "transformed the world, socially as well as materially, into a complex, adaptive system characterised by compounding interconnectedness, complexity, and uncertainty." (Kirton, 2016, p.15).

The G20, therefore, has been variously described as a "systemic hub" for governance (Kirton, 2016, p.14) and as an "improvised crisis committee" (Cooper, 2010) for the world. The G20's structure and modus operandi, which has expanded from financial regulation to elements as varied as security and culture, has made it a flexible network for global governance. The G20's members span multiple multilateral and bilateral relationships, allowing it to absorb, modulate, and adapt to the various influences present within and without the forum. As a result, member countries are given a very wide latitude to seek national and international 'portfolios' of interactions. An overarching agenda does not limit the depth or width of engagement which a country may choose with regard to a particular domain and chosen partners. In short, countries are free to pursue engagement on a needs basis, within a conducive environment where offers and interests are propositioned. This feature of the G20 allows for agendas to be negotiated without any substantive or procedural straitjackets, infusing deliberations around global supply chains with the necessary expansive latitude.

G20 Bazaar: Resolving Informational Asymmetry

Of all empires and other countries, it is arguably only the U.S.A. whereby all of their critical supply chain requirements can be somewhat met within its empire, one way or another. Nonetheless, the U.S.A. is in no position to become an autarky, with its supply chains spreading globally across geographies encircling all countries. Therefore, with globalised supply chains, even powerful empires have a dependence on thousands of nodes spread across the world, requiring engagement and negotiation. China's manufacturing prowess too, for example, needs a regular supply of critical commodities, while India's rapidly growing economy requires steady investments and acquisitions of technologies. In a VUCA world, Naturally, countries require cooperation to build mutually beneficial, resilient supply chains.

Countries have their own peculiar needs, priorities, and economic and strategic vulnerabilities, which need international supply chain linkages to be satisfactorily managed. An implicit precondition is the willingness to resolve informational asymmetries between countries. A country needs to know which other countries have the resources or capabilities that the former seeks. Simultaneously, other countries will not know what resources or capabilities to prioritise as negotiation points if their importance to a particular subject country is unknown. Owing to such an informational asymmetry, the supply chain needs of both countries remain unsatisfied or require additional resources notwithstanding the potential for synergies (Hamada & Sunder, 2005). In addition, as supply chain resilience becomes a strategic consideration, the evaluation of competing alternatives becomes important, which in turn requires minimising informational asymmetry.

Therefore, by extending its role as a systemic hub for global governance, the G20 can evolve mechanisms to act as a global bazaar which can effectively deal with the aforementioned asymmetries. The G20's unencumbered fuzzy logic enables countries to freely showcase, identify, and discuss potential supply chain and/or trade relations in an institutional setup which can reduce some of the asymmetry. While the most obvious beneficiaries will belong to the realm of South-South (or rather, East-East) cooperation, the G20 as a bazaar is equally useful to facilitate, mediate, and negotiate agendas between the broader West and the broader East. Additionally, the role of non-State actors within global supply chains, which are not amenable to regulation per se but negotiated international management (MacDonald, 2014), is an agenda which the G20 can address.

Rare Earths Bazaar

Within the broad category of strategic minerals, a particular set of metals occupies a privileged position. These are rare earths, a group of 17 elements, the so-called 14 f-block elements along with lanthanum, yttrium and scandium. Each of these elements has very specific properties, and substituting one rare earth with another is often not possible in hi-tech applications. Every piece of modern electronics, whether of civilian, military, or dual-use, depends on the supply of specific rare earths. Neodymium and dysprosium are well known in the context of permanent magnets used in any system of location guidance in civil or military domains. The essentiality of these resources, and certain peculiarities of global rare earth supply chains, renders the G20 as being amenable and also appropriate to rare earths diplomacy.

The international rare earths market for processed and ultra-pure metals, which is necessary for everything ranging from permanent magnets to semiconductors, is principally a two-body problem with the U.S.A. and China being competing supply chain pivots (Bhattacharya, 2022). Despite some innovation in specific technologies that do not depend on rare earths, the overall trajectory for key technologies, such as those involved in clean energy, are increasingly rare earth intensive (International Energy Agency, 2022). Countries like India, Australia, and Japan are only beginning to make material advances in these supply chains.

1. China exercises massive control over rare earth supply chains, but its control has been steadily decreasing over the years (United States Geological Survey, 2021). Also, China has mastery over separation and refining, but it cannot source all rare earths domestically; its largest imports of ores are from rival U.S.A. and war-torn Myanmar (Shanghai Metals Market, 2022). China has successfully weaponised its hold over rare earth supply chains time and again (Zhang et al., 2015; Humphries, 2010). Availability of imports from the U.S.A. is bound to be limited in the future, both because of America restarting production as well as due to strategic concerns. The recent push for environmental regulation is bound to decrease production, and perhaps even degrade some capabilities.

2. The U.S.A., which still has a formidable institutional memory of rare earth chemistry, intends to de-risk itself from China's dominance. To this end, it has mobilised defence funds to restart end-to-end production of rare earth products, with not just mining having commenced but separation facilities already under construction (Menon & Sharma, 2022). The U.S.A. is poised to be substantially self-reliant in this strategic input sector in the coming few years.

The above dynamic has great relevance for all countries within the G20 as well as beyond, and the supply chain uncertainty with regard to rare earths presents an opportunity for the G20 to operate as a bazaar. The rare earth supply chain is an input into the lucrative semiconductor supply chain, as well as those of high-value industries like green energy. The U.S.A.-China dynamic, as also the increasingly rare-earth intensive direction of modern technology (Gielen & Lyons, 2021), will necessarily present rare earth supply chains as being both increasingly strategic and lucrative.

Currently, the global rare earth supply chain is geographically concentrated in a few countries (Pawar & Ewing, 2022). The rare earth supply chain, partly due to this concentration and also due to its likelihood of weaponisation, is prone to severely disruptive price fluctuations having severe knock-on effects on downstream industries. This state of affairs is insufficient to cater to upcoming demand caused by technological progress, and is too fragile for all the parties involved. The impetus for diversification and resilience, i.e., for more countries and units joining the supply chain, is thus universal. Crystallising this intention into an array of substantial linkages, within an overall supply chain governance scheme for expansion-cum-resilience, requires a commensurate forum for rare earth diplomacy—a bazaar.

At the time of writing, there are some key multilateral initiatives pertaining to rare earths: cooperation at the Quad level (Nikkei Asia, 2021), and the U.S.A.-driven Minerals Security Partnership (Home, 2022) come to mind. There has also been significant bilateral action to secure rare earth supplies and/or technology: examples are Japanese investments in Australia's Lynas (Parker, 2023), American interest in Malaysia (Free Malaysia Times, 2023), and cooperation between Australia and India in the field of exploration (Australia Ministers for the Department of Industry, Science and Resources, 2020).

The narrow focus and membership in all of these initiatives show that a gap exists where potential participants are not adequately identified or engaged with. Multilateral initiatives so far are bound to exclusions implicit to the dynamics of empires, while bilateral engagement is, by definition, very selective. For a supply chain as indispensable as that for rare earths, there is no cross-empire forum also having the presence of middle powers which can nurture broader engagement. The G20, acting as such a forum, can align both incentives and the crossflow of information to allow countries to offer and consider rare-earth specific initiatives. Therefore, the G20 can catalyse rare earth supply chain relationships ranging from bilateral to global scopes. As one can expect, informational asymmetries present a big hurdle for these relationships to form: a promising and prominent economy like India is only beginning to undertake explorations-at-scale to identify reserves while considering important policy adjustments (Bhattacharya, 2022), having had no forum in the past to evaluate the global rare earth supply chain and thereafter acquire key technologies to move forward.

Exploration, mining, refining, separation, and metallurgy are all distinct stretches of the rare earth supply chain, with different countries having different potentialities in each of the above. Both China and the U.S.A., the dominant players in the field, seem to be interested in some degree of resilience-driven diversification, which is an opportunity for other countries to enter the rare earth supply chain. Thus, initiatives of the nature described above are being aggressively taken up by these two empires. Similarly, Europe has shown interest in diversification (European Parliament, 2022), and India is seeking to scale its rare earths efforts across all stages of the supply chain.

Here, the G20 can bring together varied players at a common platform, where countries can pitch their respective potentials and commence a fluid supply chain dialogue punctuated by 'fuzzy' offers and counteroffers. A free flow of market-relevant information, peppered with the potentialities of new linkages, all within an overall interactive framework, will result in both an expanded as well as resilient rare earth supply chain. This would be a beneficial outcome for all—new entrants as well as old hands.

What the G20 can do, thus, is to foster the following conversations, and ultimately catalyse need- based bilateral, multilateral, or G20-wide agreements or investment regimes:

1. Which countries have reserves, or are likely to have reserves, of required rare earths? Can partnerships in exploration capabilities be struck?
2. Can long-term mining, ore export, and processing deals be struck with countries to diversify supply chains? Can environmental and technical standards be enforced by setting up or investing in appropriate facilities at source?
3. Can the technology stack needed for separation be replicated or even innovated upon using chemistry talent available beyond the select few facilities currently online? Can resilient networks of separation facilities with assured access to acceding States be set up?

With the rare earth supply chain in flux, and the G20's unique institutional set-up in place, rare earths can be taken up as a pilot project of sorts to extend the G20's character of being a multifaceted global governance institution to a supply chain stabilisation and development role as well. With a more antifragile global rare earth supply chain, a number of supply chains for downstream industries, i.e. practically anything involving electronics, will also increase in resilience, a priority that follows from most countries' (and empires') cost-benefit matrices. The overall impact may also be developmentally significant for a number of developing countries, as they may enter hitherto inaccessible supply chains, see standards improve, and witness knock-on economic growth. Above all, one may be able to place some restraints on the intensity and modality of economic warfare, the collateral damage of which is global.

In addition to the foregoing, India can further the above ideas in a multitude of ways. India has big rare earth reserves, it is expanding its capacities, and carrying on with further explorations. India's status as an empire, which is also willing to engage partners from across the West, East and the South, places it in a position to take the interests of globally dispersed supply chains forward. India can be an anchor for the G20's rare earth supply chains, perhaps by experimenting with endeavours such as the following:

1. The G20 does not have a central secretariat, unlike most multilateral institutions. While this reflects the G20's flexible and sui generis institutional architecture, it has a few drawbacks. A limited, G20 rare earths information fusion centre can be hosted by India. Such a centre can have an agreed-upon protocol for information exchange, perhaps running on a blockchain, which allows the source country to effectively control and track access to such information.
2. India can frame and operationalise a G20-wide rare earth supply chain resilience program, which would focus on building in redundancies and buffer capacities across the rare earth supply chain. This would also channelise investments across the global South, build capacities and impose standards across the global South.
3. India can prepare the ground for a G20-wide agreement on minimum export commitments and/or global price bands on rare earth products from signatories, to limit collateral damage in case any producer intends to weaponise its supply chain involvement. In many ways, this will be an analogue to arms control treaties in the field of economic warfare, which will be an important precedent for similar agreements in other fields, and advance the G20's legacy of systemic hub governance.

Conclusions

The very origins of the G20 lie in the confluence of two phenomena: the rising importance of the East, and global crises escalating rapidly through contagion effects spreading across globalisation's interconnections. Currently, the tensions in the Amerisphere arising from the relative rise of India, Russia, and China as powers of the first magnitude constitute the birth pangs of a new world order, the final (or at least metastable) shape of which is yet indeterminate. The present transition state in international affairs not only concerns itself with the ordering of global powers, but also the modalities and assumptions with which countries can interact; the 'ground rules' for all international exchange are subject to torsion and tension. In such a world, supply chains form both the basis of modern economic life as well as networks over which contagions can transmit themselves, compounded by a variety of difficult to predict domino effects. Managing supply chain dynamics—a role which is as delicate as it is contested, requires certain preconditions which are met only by the G20. International understandings over economic warfare in general and supply chains in particular are analogous to arms control treaties during the cold war era: they are instruments of restraining great power rivalries from spiralling uncontrollably to the common detriment.

Supply chain measures in the rare earths space seem to be low hanging fruits for G20-led management due to certain factors as described above. Beyond the G20, India has been a pioneer in forming groupings such as the International Solar Alliance, i.e. thematic groupings where broad agendas drive negotiations on mechanisms. The G20's architecture possesses both legitimacy and flexibility which can be successfully built upon to carry the task out, even as India's own strengths in navigating prickly issues of organisational neutrality and developmental measures are steadily growing.

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ARTICLE

Science, Technology and Innovation and India’s G20 Presidency

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Introduction

The Group of Twenty (G20) is an intergovernmental forum of the world’s major economies. It was established in 1999 in response to the Asian financial crisis and has since become the premier forum for international economic cooperation. The G20 group of countries includes the world’s most advanced countries in the field of science, technology and innovation. They also include major low- and medium-income countries which are making major efforts in science and technology. The G20 represents a major part of the global effort in STI and applying it to various challenges and pursuing new knowledge. A number of G20 forums and groups have been addressing science, technology, and innovation-related issues. This reflects the fact that STI is cross-cutting and permeates several domains of economic and social development. This article examines the discussions on Science, Technology and Innovation issues under the Indian Presidency of the G 20, in various forums and groups such as the S20 engagement group, and ministerial groups.

Background

The G20 group consists of the major economies of the world with major investments in Science and Technology. Some key indicators are given in Figure 1. These include Gross Expenditure in R & D (GERD), Researchers per million, and research outputs.

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Figure 1: Key Indicators of the Major G20 Countries

Country	GERD percent of GDP[1]	Researchers per million[2], 2019	Publications, (thousands), 2022[3]	Patents applied for, (thousands), 2020[4]
Argentina	0.53	1237	16	0.9
Australia	1.83	4539	124	2.4
Brazil	1.17	888	93	5
Canada	1.7	4516	130	4.5
China	2.41	1585	1005	1345
France	2.35	4927	123	13
Germany	3.11	5393	202	42
India	0.66	253	274	23
Indonesia	0.28	396	43	1.3
Italy	1.53	2672	152	10
Japan	3.27	5455	139	227
Mexico	0.3	349	32	1.1
Russia	1.09	2722	108	24
S Korea	4.80	8714	102	180
Saudi Arabia	0.52	701	58	1.3
South Africa	0.61	484	34	0.5
Türkiye	1.09	1775	71	8
UK	1.72	4684	234	12
USA	3.42	4821	698	270

Source: (1 and 2) UNESCO (3) SJR (4) Index Mundi

The G20 countries present a wide range of key indicators of STI development, making them a highly diverse group. This is reflective of the wide variations in economic development among them.

G20 in STI

The G20 is the premier forum for international economic cooperation, and it has an important role to play in science, technology, and innovation (STI). The G20 countries account for over 80 per cent of global investment in R&D and 70 per cent of patent applications. They are also home to some of the world's leading universities and research institutions. The G20 can play a leading role in promoting STI cooperation and collaboration among its members. This can help to accelerate the pace of innovation and address global challenges such as climate change, disease, environment and biodiversity.

Evolution of G20 Discussions on STI

Science, Technology, and Innovation (STI) has played a key role in the G20. The G20 members recognise that STI is essential for driving economic growth, creating jobs, and addressing global challenges such as climate change and pandemics. In 2016, the G20 Leaders endorsed the G20 Blueprint on Innovative Growth, which set out a vision for STI-driven growth and prosperity. The Blueprint identified five key areas for cooperation:

1. *Innovation-driven growth:* The G20 members committed to creating an environment that fosters innovation and entrepreneurship. This included measures to support research and development, promote technology transfer, and improve access to finance for innovative startups.
2. *Innovation and entrepreneurship:* The G20 members committed to supporting the development of a strong innovation ecosystem, including through investments in education and skills training, and by promoting gender diversity in STI.
3. *Priority areas for STI cooperation:* The G20 members identified a number of priority areas for STI cooperation, including clean energy, climate change, health, food security, and disaster risk reduction.
4. *Modalities of STI cooperation:* The G20 members agreed to cooperate on STI through a variety of mechanisms, including joint research projects, policy dialogue, and capacity building.
5. *Science and technology human resources and innovative talent:* The G20 members committed to investing in science and technology education and training, and to promoting the mobility of scientists and researchers.

The G20 has also established a number of specific initiatives to promote STI cooperation, including (1) the G20 Global Science and Technology Partnership (GSTP), established in 2015, with a focus on a number of priority areas for STI cooperation, including Clean energy, Climate change, Health, Food security, and Disaster risk reduction (2) The G20 Global Innovation Initiative (GII), launched in 2017 to promote innovation and entrepreneurship in the G20 countries, with focus on priority areas for innovation, including New technologies, Entrepreneurship, Skills development, and Innovation ecosystems. The G20's focus on STI has become increasingly important in recent years. In 2020, the G20 Leaders issued a Declaration on Science, Technology, and Innovation, in which they pledged to work together to accelerate the development and deployment of STI solutions to global challenges such as COVID-19 and climate change.

Discussed below are some of the developments in STI within the G20 during the Indian Presidency 2023.

G20 Research and Innovation Initiative Gathering (RIIG)

The G20 Research and Innovation Initiative Gathering (RIIG) is a new initiative under India's G20 Presidency. It aims to promote international scientific cooperation and develop sustainable solutions for science-driven equity by Sharing best practices, collaborating on research projects, and Developing policies to promote equitable access to the benefits of research and innovation. Five RIIG meetings have been held so far in 2023, each with a different thematic focus: (1) Inception meeting in Kolkata, India (2) Materials for sustainable energy in Ranchi, India (3) Circular bio-economy in Dibrugarh, India (4) Eco-innovations for the energy transition in

Dharamshala, India (5) Sustainable blue economy in Diu, India.

The G20 Research Ministerial Meeting was held in Mumbai, on July 5, 2023. The Outcome Document and Chair's Summary[5] reaffirmed the critical role of research and innovation as an enabler for inclusive and sustainable development, gender equality, diversity, empowered citizenship, environmental integrity and protection; peace, prosperity and wellbeing in the spirit of Vasudhaiva Kutumbakam (One Earth, One Family, One Future). It recognised the importance of responsible research and innovation guided by the best available science; just and inclusive transitions; digital technologies and their impact on societal and industrial transformation; adoption of initiatives that promote lifestyles for sustainable development. Recognising the role of research and innovation as a key driver to achieving socioeconomic and technological progress it encouraged working towards common principles that underpin open, transparent, reciprocal and accountable international research cooperation through dedicated multilateral dialogues. It also recognises that research and innovation have the potential to positively impact global sustainable development and foster a better understanding between nations through science diplomacy.

G20 Research Ministers expressed commitment to achieving a resilient, inclusive, and sustainable future. They also reaffirmed their commitment to open, equitable and secure scientific collaboration in the identified priority areas for developing solutions that address societal and global challenges. They acknowledged that in the pursuit of sustainable development, there is a need to expand the production and utilisation of clean energy and to promote affordable, reliable and sustainable energy for all. The important role which science, technology and research play in supporting a more circular and sustainable bio-economy as also the need for innovation across all industrial supply chains, from raw materials to finished products, while meeting food security needs, were recognised. The Ministers also stressed the need to further develop capacities for more and better sustained coastal and ocean observations, monitoring and forecasting systems, through enhanced international coordination and cooperation for achieving the objectives of a sustainable blue economy or ocean-based economy. The G20 Ministers also expressed their commitment to encourage the mobility of students, scholars, researchers and scientists across research and higher education institutions through mobility programmes.

Building on the discussion which began in 2022 under the Indonesian G20 Presidency and continued under the Indian G20 Presidency, the Ministers recommended for consideration of Sherpas elevating the status of G20 RIIG to a formal Working Group, i.e., G20 Research and Innovation Working Group (RIWG) under the Sherpa Track. The proposed RIWG would, inter alia, maintain the continuity of the inter-year agenda under the Research Ministerial Meeting.

The Science 20 Engagement Group

The Science 20 (S20) Engagement Group of the G20 is a forum for the national science academies of the G20 countries to discuss and develop science-based policy recommendations. It was established in 2017 during Germany's G20 presidency. The S20 works through a series of task forces, each of which focuses on a specific thematic area. The task forces are composed of leading scientists and experts from the G20 countries. The S20 also holds a number of workshops and conferences throughout the year. The S20's policy recommendations are presented to the G20 leaders at the annual G20 summit. The recommendations are also shared with other G20 engagement groups, such as the Business 20 (B20) and the Civil 20 (C20).

The theme of the S20 for India's G20 Presidency was "Disruptive Science for Innovative and Sustainable Development." (6). Within this broad theme, the deliberations –were held in different parts of India on three sets of issues: Universal Holistic Health, Clean Energy for a Greener Future, and Connecting Science to Society and Culture. The consultations also included an Inception meeting in Puducherry and a Summit meeting in Coimbatore. The Indian Institute of Science (IISc) was the Secretariat for S20 India.

The Science 20 (S20) Summit was held on 22nd July 2023 at Coimbatore, Tamil Nadu, with over 100 delegates/ participants from G20 members and invited Countries and International Organisations. The text of the Science20 Communique[6] consists of subthemes: 'Clean Energy for Greener Future,' 'Universal and Holistic Health,' and 'Science for Society and Culture.' These areas of focus aimed to address crucial challenges and create science-driven solutions to promote sustainable development. The draft Communique provides policymakers with valuable science-driven recommendations, emphasising the importance of collaboration among G20 nations. The text of the communique was finalised by all the participating G20 Members and Invited Countries and International Organisations.

Recognising the role of disruptive science in advancing sustainable development, the S20 affirmed the role of strengthening international cooperation to help achieve clean energy for a green and just future, universal holistic health and having better pathways for connecting science to society, culture and heritage. On Energy, the S20 recommended increased cooperation in areas such as grid integration of renewable electricity, hydrogen produced from zero and low-emission technologies and its derivatives (such as ammonia, biofuels, e-fuels), and energy storage. It was agreed to establish a Mission Energy Access that aims to greatly accelerate clean energy access efforts across the developing world, thereby ensuring that the ongoing clean energy transition truly leaves no one behind. The S20 called for action on the following areas - development of non-resistance-forming drugs and novel antibiotics including the use of artificial intelligence (AI), machine learning (ML) and federated machine learning, expanding joint efforts on mental health with an emphasis on community-centered, primary healthcare-led, and telehealth-supported services and deepening collaboration on traditional medicine and knowledge.

It was agreed to initiate a Global Digital Heritage Initiative, which is aimed at preserving global heritage, both tangible and intangible, through the application of digital and cyber-physical technologies. This initiative would represent a paradigm shift to harness the transformative potential of science and technology to both preserve and broaden access to the rich heritage and culture of all G20 countries and other parts of the world.

The establishment of an International Platform on Emerging Disruptive

Technologies was also recommended, which would serve as a critical platform to generate and disseminate knowledge to help navigate the interfaces between science, technology, law, and policy.

Under the theme of Universal and Holistic Health, it was agreed that there is an urgent need to focus on well-being and wellness rather than specific dimensions of health. Dissemination of health information and strengthening microbial surveillance and prediction systems, monitoring wildlife, veterinary populations and human communities are all important to enable early detection and prediction of potential pathogens with pandemic potential.

Chief Science Advisers Roundtable

The G20 Chief Science Advisers Roundtable (G20-CSAR) is a new initiative launched by India during its G20 Presidency in 2023. The G20-CSAR is a forum for the Chief Science Advisers (CSAs) of the G20 countries to discuss and collaborate on science and technology (S&T) issues of global importance. The G20-CSAR was launched in recognition of the growing importance of S&T in addressing global challenges such as climate change, pandemics, and sustainable development. The G20-CSAR provides a platform for CSAs to share best practices, coordinate policies, and develop joint recommendations to address these challenges. The G20-CSAR agenda is focused on four key themes: (1) Science for One Health: This theme focuses on the role of S&T in preventing and responding to pandemics and other zoonotic diseases. (2) Science for Climate Action: This theme focuses on the role of S&T in mitigating and adapting to climate change. (3) Science for Sustainable Development: This theme focuses on the role of S&T in achieving the Sustainable Development Goals. (4) Science for Inclusive Growth: This theme focuses on the role of S&T in promoting inclusive and equitable economic growth.

The G20-CSAR is an important initiative for promoting international cooperation on S&T issues. By bringing together the CSAs of the G20 countries, the G20-CSAR can help to ensure that S&T is used to address the most pressing global challenges.

The second meeting of the G20-Chief Science Advisers' Roundtable (G20-CSAR) was held on 28 August 2023, in Gandhinagar, Gujarat. It adopted an Outcome Document and Chair's Summary.[7] The meeting recognised the importance of sustained engagement of science advisers globally on key issues. On One Health, the meeting stressed that interdependent health threats to human, animal, plant and environmental health should be addressed collectively through the One Health approach and recommended connections and continued engagements between 'One Health Institutes' for facilitating collaboration in this space.

On synergising global efforts to expand access to scholarly scientific knowledge the meeting stressed the need to enable immediate and universal access to appropriate publicly funded scholarly scientific knowledge to communities within and beyond G20 members. On Diversity, Equity, Inclusion, and Accessibility (DEI&A) in Science and Technology, the meeting noted that addressing structural inequalities is central to increasing DEI&A in the scientific and educational ecosystem, nurturing, and growing critical scientific human capital, and fulfilling our shared societal commitments. It recognised the importance of a diverse and inclusive workforce that reflects the diversity of societies in advancing science and technology. The meeting recommended that traditional and indigenous knowledge systems be taken into account with contemporary science to foster evidence-based innovations that are culturally- inspired and locally relevant, and emphasised that the plurality of languages and knowledge systems be duly recognised in any inclusion-related policy discourse. The Indian Presidency was thanked for launching this initiative.

Agriculture

The G20 Agriculture Chief Scientists (MACS) group is a forum for the chief scientists of the G20 countries to discuss and coordinate on agricultural research and innovation. It was established in 2012 by the G20 agriculture ministers in response to the growing challenges of food security and nutrition in the face of climate change, population growth, and other global trends. The MACS group meets annually to discuss and develop common research agendas, share best practices, and promote collaboration among G20 countries. The 100th meeting of the MACS group was held in Varanasi, India, in April 2023. The theme of the meeting was "Sustainable Agrifood Systems for Healthy People and Planet."

The meeting recognised[8] the importance of digital transformation of agriculture and food systems in improving sustainability and outcomes for farmers. It called for cooperation in research and extension to improve responsible, sustainable and inclusive use and application of digital technologies for food production and safety, climate resilience, circular economy principles, and for preventing food loss and waste. Recognising the importance of locally adapted crops it called for continued R&D efforts to provide inclusive solutions for climate-resilient, nutritious, locally adapted, indigenous and underutilised grains. It supported the launch of the "Millets and OtHer Ancient GRains International ReSearcH Initiative (MAHARISHI)". It also supported India's proposal to organise a workshop on climate change, sustainable and climate-resilient agricultural practices and actions to make agriculture a part of the solution to the climate crisis and called for cooperation and research on transboundary diseases, antimicrobial resistance and prevention of zoonotic disease emergence among. It supported the proposal to organise an expert meeting on the 'One Health' approach for identifying opportunities to undertake research through collaborations.

The Millets and other Ancient Grains International Research Initiative were launched under a G20 MACS Global Research Collaboration Priority (GRCP) for a 2-year period, to facilitate research collaboration on climate-resilient and nutritious grains including Millets and other underutilised grains. This will supplement the efforts undertaken under the International Year of Millets 2023 (IYoM 2023) programme initiated by the United Nations General Assembly (UNGA). The MAHARISHI intends to cooperate with public and private organszations, making efforts to advance research on these grains. The MAHARISHI secretariat will be based in the Indian Institute of Millets Research (IIMR), Hyderabad with technical support from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT).

Digital Economy

The G20 Digital Economy Ministers Meeting (DEMM) is a forum for the digital economy ministers of the G20 countries to discuss and collaborate on policies and initiatives to promote digital transformation and economic growth. The DEMM was first held in 2017 in Düsseldorf, Germany, and has been held annually since then. The DEMM was established in recognition of the growing importance of the digital economy to the global economy. The digital economy is now worth trillions of dollars and employs millions of people around the world. It is also playing a key role in driving innovation and economic growth. The DEMM agenda has evolved over time to reflect the changing landscape of the digital economy. In the early years, the DEMM focused on issues such as broadband connectivity, digital skills development, and e-commerce. In recent years, the DEMM has also expanded its focus to include issues such as artificial intelligence, data governance, and cybersecurity. In 2019, the DEMM adopted the G20 Principles for the Digital Economy, which are a set of guidelines for the development and governance of the digital economy. The DEMM has also helped to advance initiatives such as the G20 Digital Village and the G20 AI Principles. Key themes that have been discussed at the DEMM in recent years include Digital transformation and economic growth, Digital skills and inclusion, Data governance and cybersecurity, and Emerging technologies.

The G20 Digital Economy Ministers Meeting, Bengaluru, August 19, 2023, discussed digital innovation and inclusion, digital skilling, and security in the digital economy. The meeting was a culmination of the four Digital Economy Working Group Meetings that had been held earlier in the year. The meeting adopted a 29-paragraph outcome document and chairs summary ,[9] and several annexures - (1) The G20 Framework for Systems of Digital Public Infrastructure (2) The G20 High-Level Principles to Support Businesses in Building Safety, Security, Resilience, and Trust in the Digital Economy (3) Took note of the Indian Presidency's document on G20 Toolkit on Cyber Education and Cyber Awareness of Children and Youth (4) Welcomed the G20 Toolkit for Designing and Introducing Digital Upskilling and Reskilling Programmes (5) Welcomed the G20 Roadmap to Facilitate the Cross-Country Comparison of Digital Skills.

The ministers reaffirmed their commitment to building an enabling, inclusive, open, fair, non-discriminatory, and secure digital economy. They also discussed a number of specific initiatives to advance this goal, including (1) Digital Public Infrastructure for Digital Inclusion and Innovation: The ministers agreed to work together to develop and promote digital public infrastructure that is accessible, affordable, and inclusive. They also discussed the importance of promoting open standards and interoperability. (2) Building Safety, Security, Resilience and Trust in the Digital Economy: The ministers discussed the importance of cybersecurity and data privacy for promoting trust in the digital economy. They also discussed the need to develop international norms and standards for cybersecurity and data governance. (3) Digital Skilling for Building a Global Future-Ready Workforce: The ministers discussed the importance of digital skills for the future of work. They agreed to work together to develop and promote digital literacy and skills training programmes.

Health

The G20 Health Ministers Meeting (HMM) is a forum for the health ministers of the G20 countries to discuss and collaborate on global health issues. The HMM was first held in 2017 in Berlin, Germany, and has been held annually since then. The HMM was established in response to the growing recognition that global health challenges, such as infectious diseases, antimicrobial resistance, and chronic diseases, require a global response. The HMM provides a platform for the G20 countries to share best practices, coordinate policies, and commit to joint actions to improve global health. The HMM agenda has evolved over time to reflect the changing global health landscape. In the early years, the HMM focused on issues such as pandemic preparedness and response, global health security, and access to essential medicines. In recent years, the HMM has also expanded its focus to include issues such as noncommunicable diseases, mental health, and climate change and health. The HMM has played an important role in promoting international cooperation on global health issues. In 2017, the HMM adopted the G20 Global Action Plan on Antimicrobial Resistance, which is a comprehensive plan to address the growing threat of AMR. The HMM has also helped to advance initiatives such as the G20 Global Health Security Agenda and the G20 Mental Health Action Plan. Issues that have been discussed at the HMM in recent years were addressed during the Indian presidency also.

The G20 Health Ministers meeting was held in Gandhinagar, Gujarat, on August 18th - 19th 2023. It discussed major global health priorities and challenges and reaffirmed the commitment to continue strengthening the Global Health Architecture. A 25-para outcome document and chairs summary were adopted.[10] The ministers discussed a wide range of global health issues, including Pandemic preparedness and response, One Health, Strengthening health systems, Access to essential medicines and vaccines, Noncommunicable diseases, Mental health, and Climate change and health. They agreed to continue working together to promote multilateral cooperation on global health issues, and to support the World Health Organisation as the leading global health authority.

Space

The G20 Space Economy Leaders Meeting (SELM) is a forum for the leaders of the G20 countries to discuss and promote the development of the global space economy. It was established in 2021 by the Italian G20 Presidency and held its first meeting in Venice, Italy. The meeting is typically held once a year and focuses on a different theme each year. The SELM is an important platform for the G20 countries to collaborate on space-related issues.

The SELM also plays a role in promoting international cooperation in the space sector and supporting the development of the space economy in developing countries. The SELM is a relatively new initiative, but it has the potential to play a significant role in shaping the future of the global space economy. By bringing together the leaders of the world's largest economies to discuss space-related issues, the SELM can help to promote cooperation and investment in the space sector, which can lead to the development of new technologies and applications that can be of benefit.

The 4th Space Economy Leaders Meeting (SELM) was held in Bengaluru during July 6-7, 2023 with the theme: Towards a New Space ERA (Economy, Responsibility & Alliance). Recalling the reaffirmation at the second SELM (2021) to address the growing hazard of space debris and increasing congestion in Earth's orbit, the delegates noted the benefit of preserving certain orbital regimes for safe human space flight activities for the benefit of all nations. The delegates also noted the potential benefits of moving towards more sustainable manufacturing of space systems and progressive use of eco-friendly and green propulsion systems. Recognising the increasing number and diversity of players in space, leaders stressed the importance of bilateral and multilateral partnerships involving the space agencies, industries and academia to address the challenges to the long-term sustainability of outer space. Leaders have also encouraged all space-faring nations to promote international cooperation and capacity building in support of the space-aspiring nations.[11]

Energy

The G20 Energy Transition Ministers Meetings were first held in 2017 during Germany's G20 presidency. The meetings were established in response to the growing need for international cooperation on energy transitions. The subsequent meetings have evolved to reflect the changing global energy landscape. The 2019 meeting focused on the role of energy transitions in supporting economic growth and job creation. The 2021 meeting focused on the importance of energy transitions in achieving the goals of the Paris Agreement on climate change. The 2023 meeting, which was held in India, was the first G20 Energy Transition Ministers Meeting to be held in a developing country. The meeting focused on the importance of ensuring that energy transitions are affordable and inclusive for all countries, including developing countries.

The 2023 G20 Energy Transitions Ministers' Meeting was held in Goa, on 22 July 2023 for accelerating the clean, sustainable, just, affordable and inclusive energy transitions, following various pathways, as a means of enabling secure, sustainable, equitable, shared and inclusive growth.[12] The meeting reaffirmed the commitments, in pursuit of the objective of UNFCCC, to tackle climate change by strengthening the full and effective implementation of the Paris Agreement and its temperature goal, reflecting equity and the principle of common but differentiated responsibilities and respective capabilities, in light of different national circumstances. It agreed to advance technological collaboration and cooperation amongst G20 members, other international partners and multilateral institutions to strengthen energy systems. It recognised that certain minerals, materials and technologies are critical for energy transitions and there is a need to maintain reliable, responsible and sustainable supply chains of such critical minerals and materials, as well as semiconductors and related technologies. In this regard, it supported voluntary and mutually agreed technology diffusion, skill development, beneficiation at source and increased flow of finance to address the lack of capital, human or technical resources; to produce them sustainably and with a view to enhance local value creation through beneficiation.

The Indian Presidency presented several documents which were noted and welcomed These were (1) G20 High-Level Voluntary Principles on Hydrogen (2) Voluntary High-Level Principles for Collaboration on Critical Minerals for Energy Transitions, (3) Voluntary Action Plan on Doubling the Global Rate of Energy Efficiency Improvement by 2030 (4) Voluntary Action Plan for Lowering the Cost of Finance for Energy Transitions (5) Voluntary Action Plan for Promoting Renewable Energy to Accelerate Universal Energy Access.

The Ministers noted the need for accelerating the pace and scale of commercial deployment of mature clean energy technologies including solar, wind, hydropower including pumped storage, geothermal, bioenergy, heat pumps, CCUS and, nuclear energy and the need for acceleration of development and deployment of other emerging and new technologies such as electrolysers, bioenergy with carbon capture and storage (BECCS), direct air capture (DAC), high-efficiency fuel cells, ACC battery storage, and sustainable advanced biofuels, as well as, small modular reactors (SMRs).

Reflecting some differences, the Ministers noted that countries that opt to use civil nuclear energy reaffirm their role in providing clean energy and plan to collaborate, in research, innovation, development and deployment of civil nuclear technologies including advanced and Small Modular Reactors (SMRs). The importance of making efforts towards phasing down unabated fossil fuels was emphasised by some members while others had different views on the matter that abatement and removal technologies will address such concerns.

The meeting recognised the importance of sustainable biofuels and hydrogen and the need to build a sustainable and equitable global hydrogen ecosystem and noted the Presidency's initiative to establish the Green Hydrogen Innovation Centre steered by ISA. It took note of the estimate that the world needs an annual investment of over USD 4 trillion, with a high share of renewable energy in the primary energy mix.

Environment and Climate Change

The G20 Environment and Climate Ministers' Meeting (ECMM) was first held in 2007 in Paris, France. The meeting was established in response to the growing recognition of the need for international cooperation to address environmental and climate challenges. The ECMM discusses a range of issues, including Climate change, Biodiversity loss, Pollution, Land degradation, Ocean degradation, and Sustainable development. The ECMM has played an important role in shaping the G20's agenda on environmental and climate issues. It was instrumental in the development of the G20 Action Plan on Climate Change, adopted in 2009. In recent years, the ECMM has focused on a number of priority areas, including clean energy transition, biodiversity, reducing pollution, promoting sustainable consumption and production, building resilience to climate change, and climate justice, and the need to ensure that the transition to a clean energy future is equitable and inclusive.

The 2023 G20 Environment and Climate Ministers' Meeting, Chennai, 28 July 2023, adopted a 68-paragraph outcome document including 4 paragraphs which represented the Chair summary.[13] Paras 63 and 64 indicated divergent views among G20 members on the overlap mandate of the Environment and Climate Sustainability Working Group with the Energy Transition Working Group, to discuss energy issues; on the issues of energy transitions, and on the issue of disguised trade restrictions and Carbon Border Adjustment Mechanism (CBAM). Para 66 reflected geopolitical tensions related to Ukraine. The meeting adopted the 9-point Chennai High-Level Principles for a Sustainable and Resilient Blue/Ocean-based Economy and noted the 10 documents prepared by the Indian Presidency, covering various issues such as land, mining, forest fires, water, marine litter, circular economy, etc.

Key takeaways in the outcome document included - (1) Reemphasising the importance of the three Rio Conventions:

the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the United Nations Convention to Combat Desertification (UNCCD). (2) Accelerating action on environmental and climate challenges including climate change, biodiversity loss, pollution, land degradation, and ocean degradation, and (3) Promoting a sustainable and resilient recovery from COVID-19 and the need to ensure that environmental and climate considerations are integrated into all recovery efforts. In the outcome document, the Ministers committed to (1) accelerating the transition to a clean energy future, and to working together to achieve the goals of the Paris Agreement. (2) halting and reversing biodiversity loss by 2030 and working together to implement the Kunming-Montreal Global Biodiversity Framework. (3) reducing pollution from all sources, including air pollution, water pollution, and marine pollution. (4) working towards land degradation neutrality by 2030. (5) protecting and restoring marine ecosystems, and reducing marine pollution.

G20 Leaders Meeting and Declaration

The G20 Leaders Meeting adopted an ambitious 83-paragraph New Delhi Leaders Declaration on 9 September 2023.[14] Annexed were 26 documents on the various sub-group outcomes. The STI- related content appears in three of the sections of the document. The section on Sustainable Development covered health-related issues. The section on the Green Development Pact covered issues such as energy transition, climate change, environment and ecosystem protection, and circular economy. The section on technological transformation and digital public infrastructure covered digital public infrastructure, safety and security of the digital economy, promotion of digital ecosystems, digital finance, and AI. During the Summit, the Indian Presidency announced important initiatives - the Global Biofuels Alliance, and the India Middle East Europe Corridor (IMEC) that were widely welcomed and supported.

India and the Global South in G20

The Voice of the Global South meeting, hosted by India during its G20 Presidency in January 2023, was a significant event that brought together leaders from developing countries to discuss their shared challenges and priorities. The meeting was held in recognition of the fact that the Global South, which represents over 80 per cent of the world's population, is often underrepresented in global decision-making processes. The leaders at the meeting discussed a wide range of issues including Climate change and sustainable development, Global health security, Food security and nutrition, and Digital transformation. The Indian Presidency of the G20 has made a priority of giving a greater voice to the Global South. This is reflected in the fact that India has successfully steered the G20 to agree to admit the African Union as a full member of the G20 (now G21).

At the Voice of the Global South meeting Indian Prime Minister Narendra Modi announced two major initiatives - the Global South Centre of Excellence and the Global South Science and Technology Initiative. The Global South Centre of Excellence will be a hub for research and innovation on development solutions that can be scaled and implemented in other countries of the Global South. The Centre will focus on areas such as agriculture, healthcare, education, and technology. The Global South Science and Technology Initiative will aim to share India's expertise in science and technology with other countries of the Global South. The Initiative will focus on areas such as space technology, nuclear energy, and renewable energy. Both of these initiatives are significant steps forward in India's efforts to support the development of the Global South. The initiatives reflect India's commitment to working with other developing countries to address their shared challenges and achieve their development goals. In addition to these two initiatives, India also announced a number of other initiatives at the Voice of the Global South meeting, including (1) Arogya Maitri (Wellness Friendship) project: This project will provide medical supplies to any developing country hit by a natural disaster. (2) Global South Young Diplomats Forum: This forum will bring together young diplomats from countries of the Global South to discuss and collaborate on issues of common interest. (3) Global South Scholarships: This scholarship programme will provide scholarships to students from countries of the Global South to study in India.

Conclusions

The Indian Presidency of the G20 has further strengthened the engagement of the G20 members in STI as an important vehicle for economic and social development while safeguarding the health of the planet. It also strengthened the role of the global South in the G20. A number of important new initiatives were launched, including on the sidelines of the G20 leaders meeting and the meeting with leaders of the global South. The Presidency of the G20 will now be held by Brazil in 2024 and by South Africa in 2025. This period starting with the Indonesian Presidency in 2022 marks an opportunity for the global South to strengthen their role in the G20 and bring to bear STI solutions to development issues of concern to them.

Endnotes

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2 UNESCO, Researchers (in full-time equivalent) per million inhabitants, http://data.uis.unesco.org/index.aspx?queryid=3685

3 Scimago Journal and Country Rank , SJR, 2022, https://www.scimagojr.com/countryrank.php?order=itp&ord=desc&year=2022

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[12] ETMM Outcome Document and Chair's Summary, July 22, 2023, https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/ETMM_ODCS.pdf

[13] G20 Environment and Climate Ministers' Meeting- Outcome Document and Chair's Summary, Chennai, July 28, 2023, https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/ECMM%20Outcome%20document%20and%20Chair%20Summary%20(July%2028)%20FINAL.pdf

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ARTICLE

Science Diplomacy and Agriculture Development in India: A Path to Progress

Vikas Kumar*

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Introduction

Science diplomacy is a newly evolved concept and can be effectively applied in various sectors with different perspectives. Aquino (2020) states that science diplomacy is an association between science and international cooperation. Balakrishnan (2017) notes that it has a three-dimensional approach. First, science in diplomacy, which means scientific advice and input into foreign policy-making; second, diplomacy for science that promotes cooperation of international science, and third, science for diplomacy to improve relations among countries through cooperation. Further, Indian foreign policy is now more focused on science and technology to develop international cooperation, which helps to identify, facilitate and promote India's international cooperation in frontier and emerging areas of Science, Technology, and Innovation (STI) under bilateral, regional, and multilateral programmes. This can be seen in the agreement signed between the Department of Science and Technology (DST), the Government of India, with the Third World Academy of Sciences (TWAS) in the year 2015 to support cooperative efforts in science diplomacy training (DST, 2015).

The government of India has taken several steps to boost agriculture on a sustainable basis because 56.6 per cent of the population is engaged in agriculture and allied activities and plays an important role in India's economy. It contributes 17.4 per cent to the country's Gross Value Added at the current price 2014-15, 2011-12 series (DA&FW, 2021). Other ministries such as the Ministry of Science and Technology of India are also helping to boost the agriculture sector. For instance, the Ministry has developed programmes of cooperation

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with various countries and international organisations in which the Department of Agricultural Research and Education (DARE) - Indian Council for Agricultural Research (ICAR) is the participating agency in the field of agricultural research. Similarly, the Ministry of External Affairs and the Ministry of Commerce have a component of agricultural research in which DARE-ICAR participates directly or through the Department of Agriculture & Cooperation. The MoUs and Work Plans focused on agricultural research and education are implemented via visits and training of scientists, exchange of literature, exchange of germplasm, and capacity-building programmes (DARE, 2021). These activities can help to share knowledge, gain overall experience and exposure to the latest development of technology in the various countries under bilateral and multilateral cooperation of India.

Based on the above argument, this article tries to conceptualise Science Diplomacy in India and especially in the case of agricultural sector development. Broadly, this article deals with the question of how science diplomacy contributes to agricultural development in India, emphasising the following aspects:

1. To explore the concept and importance of science diplomacy in agricultural research and development in India,
2. To assess the role of science diplomacy in agricultural development in the last four decades.

Aligning with these objectives and aforementioned argument, the article has been divided into four parts, including the introduction. The second section conceptualises the concept and understands the importance of science diplomacy in agricultural research. The third section deals with the evaluation of diplomacy for agricultural development in India in the last four decades. It also talks about the types and institutions engaged in diplomacy to promote agricultural research and development. The final section concludes the argument of the paper. Thus, the next section describes the concept and importance of Science Diplomacy, keeping in view the concept regarding agricultural development.

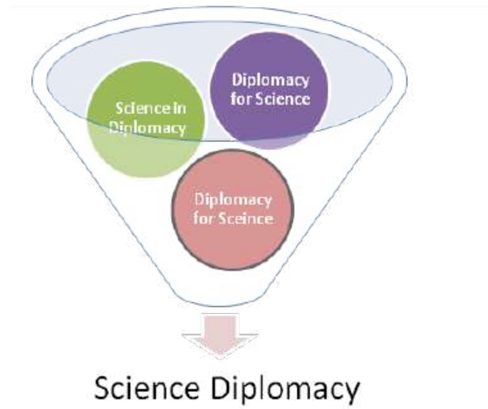
Science Diplomacy and Agriculture Development: Understanding the Concept

Science Diplomacy plays a vital role in promoting a state's foreign policy goals or inter-state interests through the use of science (Fedoroff, 2009). Flink & Schreiterer (2010) argue that science diplomacy is not only how to manage international conflicts and foreign policy but also to play the role of stakeholders in the scientific policy of a nation. Further, they state that the objectives of science diplomacy are access, promotion, and influence. Access refers to the attraction of researchers, research results, and infrastructure for science and technology. Promotion, on the other hand, refers to attracting the best researchers, students, and companies in the world, which can support a given country to be more competitive and develop innovations. Influence is about seeking spaces in international agendas, as a tool for "soft power" to attract political support to initiatives at the national or transnational level and improve international prestige and recognition.

Similarly, Copeland (2016) argues that Science Diplomacy allows the release of science and technology from institutional and national barriers to serve the problems of underdevelopment and insecurity. Birang et al. (2017) argue science diplomacy plays a role in empowering and accelerating the development, progress, and generation of wealth for countries. Further, Sege (2020) emphasises that the goal of Science Diplomacy should be the group of constructive partnerships between countries. Hence, based on these arguments, it can be said that there are various actors (i.e. governments, the international community, non-governmental organisations, civil society, and the private sector, etc.) engaged in science diplomacy.

Further, Mosquera (2020) stresses the importance of interdisciplinary groups to solve problems with the help of science diplomacy. Similarly, Echeverría (2020) states that science diplomacy improves the relationship between scientists, politicians, and civil society and also needs a financing programme that promotes international research. Gluckman et al. (2017) also focus on three categories of Science Diplomacy actions and these actions relate to processes for national, cross-border, or international interest. However, various scholars define science diplomacy with their perspectives, such as formal or informal technical, research-based, academic, or engineering exchanges. In this context, the Royal Society (2010) states that science diplomacy can be seen in three main types of activities; first, informing foreign policy objectives with scientific advice; second, facilitating international science cooperation; and third, using science cooperation to improve international relations between countries. The figure given below represents three different concepts of Science Diplomacy, based on their function or activities.

Figure 1: Types of Science Diplomacy



Source: Author, 2021 based on the Review of Literature

In the context of science diplomacy for agriculture, DARE-ICAR participates through programmes of cooperation developed by the Ministry of Science and Technology with various countries and international organisations. Besides this, the Ministry of External Affairs and the Ministry of Commerce also have a component of agricultural research in which DARE-ICAR participates directly or through the Department of Agriculture & Cooperation. These participations are under bilateral cooperation in research and education in Agriculture and allied fields through MoUs and Work Plans with more than 35 countries/Organisations/ Universities (Ministry of Agriculture, 2021). In light of this, this paper uses the Science Diplomacy framework, explaining how Science Diplomacy acts as a network for the promotion of agricultural research among various countries.

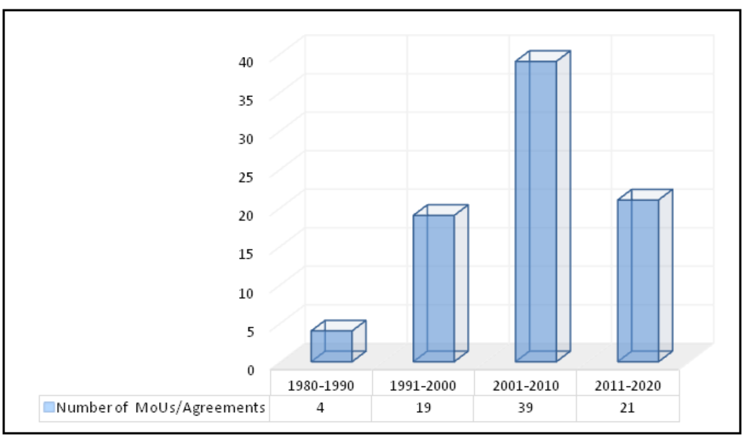
Science Diplomacy in Agriculture and Allied Areas: An Evaluation

Science diplomacy in agriculture can be seen through international cooperation in DARE-ICAR as the nodal department that functions through the MoUs/Work Plans signed with various countries/ International Organisations/Foreign Universities and Institutes. This kind of cooperation is mostly bilateral because the MoUs are signed either between the Government of India (represented by DARE) and the Government of another country (represented by their department handling agriculture) or between the ICAR and another foreign autonomous body/ university/ university. There is also multilateral cooperation wherein DARE-ICAR participates under the framework of, for instance, IBSA, BRICS, SAARC, ASEAN, etc., and the Ministry of External Affairs plays the nodal role in this cooperation. In addition to this, DARE-ICAR is involved in an active partnership with international agricultural research institutions like the CG Centres, CABI, FAO, NACA, APAARI, UN-CAPSA, APCAEM, ISTA, ISHS, etc.

In addition to this, international cooperation work in the area of agricultural research and education is carried out through study visits and training of scientists, exchange of literature, exchange of germplasm, and capacity-building programmes..DARE-ICAR provides quality and cost-effective agricultural education to international students at various levels (i.e., undergraduate, post-graduate, and doctoral levels) and need-based short-term training programmes in specialised areas. Besides this, international training programmes are also organised at various ICAR institutes and the State Agricultural Universities for human resource development to take up research, education, and extension activities in emerging areas of agricultural sciences.

The Ministry of Agriculture and Farmers Welfare has signed a total of 83 MoUs/Agreements with other countries for cooperation in Agriculture and allied sectors. This cooperation covers different

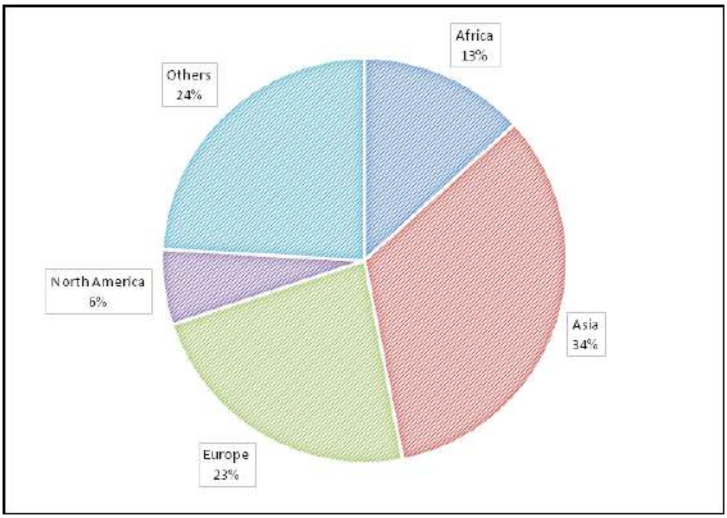
Figure 2: Number of MoUs/ Agreements Signed in the Agriculture and Allied Sector since 1980-2020



Source: Compiled by Author, 2023 from Lok Sabha q no. 4956 issues such as market access issues, capacity building, knowledge exchange through visits of scientists and technicians, exchange of genetic resources, etc. to develop technologies and practices at the farm level. It also helps to create new opportunities for trade in agricultural commodities through partnerships with other countries (Lok Sabha q no. 4956). The figure given below shows year-wise collaboration.

As can be seen from the figure above, a total of 83 MoUs were signed to enhance agricultural development in India. In the last decade (2011-2020), 21 MoU agreements were signed in the agriculture and allied sector, and from 2001 to 2010, the highest number (39) of MoUs were signed for agricultural development. One agreement started in the year 1983 between DARE and Australia to enhance agricultural research and education.

Figure: 3. Region-wise MoUs/ Agreements Signed in Agriculture and Allied Sector



Source: Compiled by Author, 2023 from Lok Sabha q no. 4956

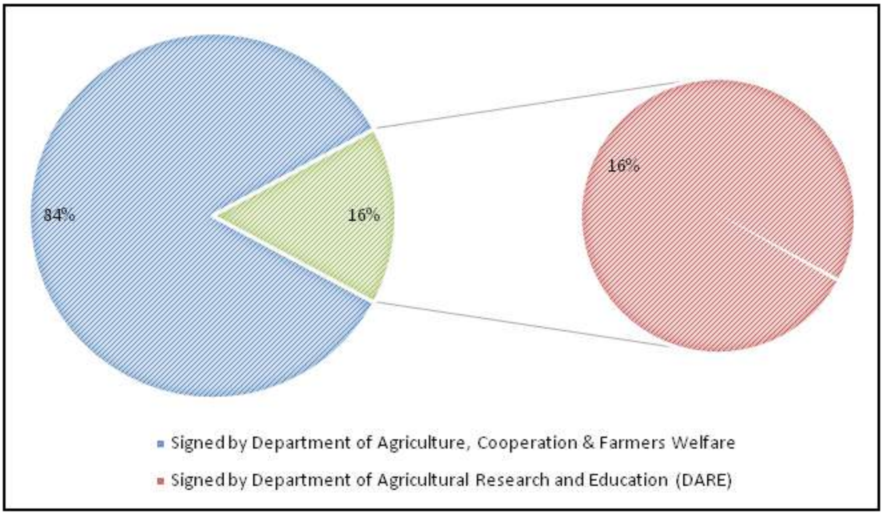
From 1980 to 1990, only four MoUs were signed with three countries, i.e., Australia, the Netherlands, and Pakistan. During the same period, two agreements were signed with the Netherlands, one with DARE and another with the Department of Agriculture, Cooperation & Farmers Welfare.

Further, it is important to see a region-wise distribution of the signed agreements and look at the total agreements signed with the countries, namely, in Asia, Africa, Europe, North America, and others. The figure is shown in detail.

The figure above gives the MoU signed for the development of agriculture by regions. One can see from the figure that the highest number of MOUs were signed within the Asia region (34 per cent) including the UAE, Palestine, Philippines, Iran, Uzbekistan, Maldives, etc. 23 per cent of MoUs were signed with countries in Europe like Austria, Armenia, Lithuania, Portugal, Poland, etc. 13 per cent of MoUs were signed with the African region,with South Africa, Kenya, Botswana, Malawi, Madagascar, etc. A few MoUs (6 per cent) were signed with countries in North/ South America for instance, Canada, Brazil, USA, etc.

DARE and the Department of Agriculture, Cooperation, and Farmers Welfare are the two main organisations in India that are involved in the MoUs agreement for agricultural development. The figure given below shows that 84 per cent of MoU agreements were signed with the Department of Agriculture, Cooperation, and Farmers Welfare for

Figure 4: Organisation wise MoUs/ Agreements Signed in Agriculture and Allied Sector



Source: Compiled by Author, 2023 from Lok Sabha q no. 4956

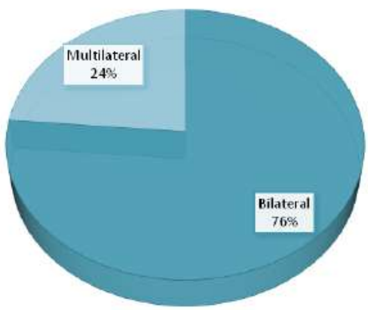
agricultural development. These MoU agreements were signed between India and countries like Japan, the UAE, the Netherlands, Australia etc. On the other hand, 16 per cent of MoU agreements are signed by DARE and countries like Panama, Morocco, Argentina, Sudan, etc. The motive behind the MoUs signed is to develop research and development (R&D) in agriculture and allied sectors.

3.1 Types of Diplomacy

Broadly, diplomacy can be separated into two parts, i.e., bilateral and multilateral. In light of this, India actively collaborated in both ways to get benefits by way of knowledge sharing and gaining overall experience and exposure to the latest developments of technology in various countries. This section deals with Bilateral International Cooperation in the field of Research and Education in Agriculture and Allied Areas. In bilateral international cooperation, DARE-ICAR has been involved directly or indirectly. In addition to this, DARE plays a role as a representative of the Government of India to sign an MoU with the government departments of other countries related to agriculture. Similarly, ICAR also signs MoUs with other autonomous bodies or institutions/universities.

The Department of Agriculture & Cooperation plays a nodal role in the MoUs/Work Plans activities. As of now, there are 42 MoUs and work plans signed between DARE-ICAR and other countries/ Organisations/Universities under multilateral and bilateral cooperation in research and education in Agriculture and allied fields. The figure given below is shown in detail.

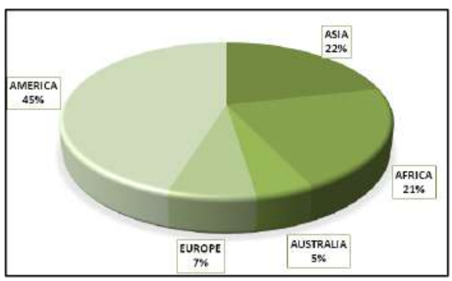
Figure 5: Types of Diplomacy MoUs /Agreements Signed in Agriculture and Allied Sector



Source: Compiled by Author, 2023 from www. dare. nic. in

The figure above depicts the types of diplomatic agreements signed i.e., bilateral and multilateral. In this context, 76 per cent of total MoUs signed for agricultural research and development are bilateral agreements. Examples are the agreement between ICAR and the Chinese Academy of Agricultural Sciences (CAAS) China, DARE-Govt. of the Republic of Eritrea, ICAR-Golden Valley Agriculture Research Trust (GART), Zambia and DARE in the M/o Agriculture, India and the Ministry of Agricultural Development, Panama, etc. Similarly, 24 per cent of MoUs were multilateral agreements such as ASEAN-India cooperation in Agriculture, DARE / ICARs role towards cooperation in SAARC and G20, Network of Aquaculture Centres in Asia – Pacific, United Nations Asian and Pacific Centre for Agricultural Engineering and Machinery and International Tropical Fruits Network, etc. However, it is important to know the region-wise participation of DARE-ICAR under bilateral cooperation in research. The figure given below states that 45 per cent of the MoUs agreement were between DARE-ICAR and the Americas, followed by 22 per cent with the Asia region and 21 per cent with the Africa region. On the other hand, 7 per cent were with Europe and 5 per cent with Australia.

Figure: 6. Region-wise DARE-ICAR Participation under Bilateral Cooperation in Research and Education in Agriculture and Allied Fields

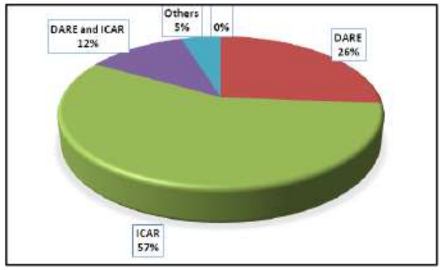


Source: Compiled by Author, 2023 from www. dare. nic. in

3.2. Engagement of Institutions under Bilateral Agreements

It is important to know the involvement of specific institutions for research and education in agriculture and allied fields and how academic and research institutions are playing a role in the development of agriculture. As it can be seen in the given figure below, there are two research institutions i.e., DARE and ICAR actively participated in the MoUs. The data shows 57 per cent of the agreement signed by ICAR and 26 per cent of the agreement signed by DARE under bilateral diplomacy. 12 per cent of MoUs were signed by both the institutions and 5 per cent of there is the involvement of other institutions such as M/o Agriculture, India and the Ministry of Agriculture and Food Industry, Socialist Republic of Vietnam and CAR-The Agriculture Development Fund, Govt. of Saskatchewan, Canada, etc.

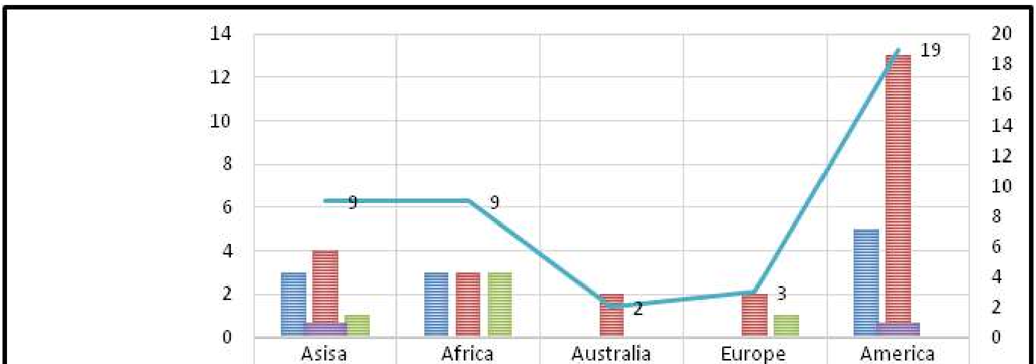
Figure 7: Institutions-wise Participation under Bilateral Cooperation in Research And Education in Agriculture and Allied Fields



Source: Compiled by Author, 2023 from www. dare. nic. in

In addition to this, region-wise involvement of institutions under bilateral

Figure 8: Region-wise Involvement of Institutions under Bilateral Cooperation



	Asisa	Africa	Australia	Europe	America
DARE	3	3	0	0	5
ICAR	4	3	2	2	13
DARE and ICAR	1	3	0	1	0
Others	1	0	0	0	1
Total	9	9	2	3	19

Source: Compiled by Author, 2023 from www. dare. nic. in

cooperation is shown in the figure given below. The data shows 5 MoU agreements by DARE in the Americas and 3 each in Asia and Africa. The same can also be seen with ICAR . For instance, 13 MoU agreements were signed in the Americas and 4 agreements in Asia, followed by 3 and 2 in Africa and Australia respectively. On the other hand, DARE and ICAR have been actively involved in the region of

Africa for research and education. There are a total of 5 agreements signed by both institutions and, out of these, 3 MoUs in Africa, 1 each in Asia and Europe.

3.3. Role of Major Institutions Involved in MoUs: DARE and ICAR

Broadly, two main institutions, namely DARE and ICAR, coordinate and participate in the field of agriculture and rural development. The details of these two institutions are discussed separately.

3.3.1. Significance of DARE

It was established in the year of 1973 under the Ministry of Agriculture. It promotes agricultural research and education in the country and provides the necessary government linkages for the Indian Council of Agricultural Research (ICAR), the premier research organisation for co-ordinating, guiding, and managing research and education in agriculture and the allied sector. It plays a role as the nodal agency for International Cooperation in the area of agricultural research and education and liaises with foreign governments, the UN, CGIAR, and other multilateral agencies for cooperation in various areas of agricultural research. Besides this, it also coordinates admissions of foreign students to various Indian agricultural universities or ICAR Institutes. It has administrative control over four autonomous bodies:

Table 1: List of Organisations under DARE

S.No.	Name of Organisation	Year of Establishment	Role and Responsibilities
1	Agrinovate India Limited (Agln)	2011	It aims to work on the strengths of DARE's Indian Council of Agricultural Research (ICAR) and promote the development and spread of R&D outcomes through IPR protection, commercialisation, and forging partnerships both in the country and outside.
2	National Academy of Agricultural Sciences	1990	Think tank and an important forum for harnessing science for enhancing the productivity, profitability, equity, and sustainability of Indian agriculture.
3	Rani Lakshmi Bai Central Agricultural University	2014	Furthering excellence in agricultural education, and research and supporting farmers in all possible ways
4	Central Agricultural University (CAU)	1993	To be a center of Excellence in teaching, research, and extension education in the field of agriculture and allied sciences.
5	Indian Council of Agricultural Research (ICAR)	1929	The Council is the apex body for co-ordinating, guiding, and managing research and education in agriculture including horticulture, fisheries, and animal sciences in the entire country.

6	Dr. Rajendra Prasad Central Agricultural University	1970	The university extends its jurisdiction and responsibility in the fields of teaching, research, and extension in the context of agriculture and allied sciences to the whole country with special reference to the State of Bihar.

Source: Compiled by Author, 2023 from https://dare.gov.in/en

- Indian Council of Agricultural Research (ICAR)
- Central Agricultural University (CAU), Imphal
- Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar
- Rani Laxmi Bai Central Agricultural University, Jhansi, UP

The major function of DARE is to oversee all aspects of agricultural research and education involving coordination between the central and state agencies and attend to all matters relating to the Indian Council of Agricultural Research. It is also concerned with the development of new technology in agriculture and allied areas. It has six organisations under DARE.

Table 2: List of CGIAR Research Centers

S.No.	Name of Centre
1	Africa Rice Center (West Africa Rice Development Association, WARDA
2	Bioversity International
3	Center for International Forestry Research (CIFOR)
4	International Center for Tropical Agriculture (CIAT)
5	International Center for Agricultural Research in the Dry Areas (ICARDA)
6	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
7	International Food Policy Research Institute (IFPRI)
8	International Institute of Tropical Agriculture (IITA)
9	International Livestock Research Institute (ILRI),
10	International Potato Center (CIP),
11	International Rice Research Institute (IRRI)
12	International Water Management Institute (IWMI),
13	World Agroforestry Centre (International Centre for Research in Agroforestry (ICRAF)
14	WorldFish Center (International Center for Living Aquatic Resources Management, ICLARM)
15	International Maize and Wheat Improvement Center (CIMMYT)

Source: https://testicar.icar.gov.in/content/international-relations accessed on 2023

3.3.2. Significance of ICAR

The Indian Council of Agricultural Research (ICAR) was established in 1929 and it is an autonomous organisation under the DARE, Ministry of Agriculture and Farmers Welfare, Government of India. It is the apex body for co-ordinating, guiding, and managing research and education in agriculture and allied areas. It works closely with the Consultative Group on International Agricultural Research (CGIAR), which is an international R&D network having 15 Research Centres shown in Table 2. India participates as a donor member of the CGIAR System and contributes substantially through CGIAR System Council mechanisms.

Among the above-mentioned list of research centres, ICRISAT has its headquarters in Hyderabad in the State of Telangana, India. ICAR participates in global agricultural research through mutual agreements and work plans. The broad areas of research collaboration with the CGIAR system include germplasm and technology development to achieve targeted crop and animal productivity and quality in India.

In addition to this, ICAR is also a nodal agency for enabling admissions of foreign students to Indian institutions in the area of agricultural education. Under this scheme, the following fellowship is provided:

- India-Africa fellowship
- India-Afghanistan fellowship
- India-Nepal fellowship
- IMTECH Scholarships for developing countries
- Netaji Subhash Chandra Bose International fellowship for doctoral research.
- NHAEP supported a post-doctoral fellowship.

Besides this, The International Relations (IR) Division was established at ICAR Headquarters with the following mandates (ICAR, 2023):

- To reach beyond borders for Agri-R&D.
- To do global technology foresight.
- To enable research proposals for foreign collaboration and funding.
- To facilitate SMD/Institute Interface with DARE as a single window and vice versa.
- To facilitate expert visitors from foreign countries to ICAR Institutes.

3.4. International Collaboration and Linkages for Agriculture Development: Recent Activities

Various research projects were signed in the last two to three years between ICAR and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Wheat and Maize Research Centre (CIMMYT), and International Centre for Agricultural Research in the Dry Areas (ICARDA). ICAR signed agreements with The State Secretary of Agro-industry of The Ministry of Production and Labour of The Argentine Republic, Western Sydney University, and International Bamboo and Rattan Organisation (INBAR), PR China for cooperation in Agricultural Research and Education for Cooperation in the field of Agricultural Research and Education.

Further, to promote and accelerate the collaborative efforts for research and training in food and agricultural policies during the year 2020-21, ICAR agreed on a work plan agreement with The International Fertilizer Development Center (IFDC), Alabama, USA. The Work Plan for the period 2020-25 was signed between ICAR and the International Food Policy Research Institute (IFPRI). Besides this, to develop agricultural research in the Global South, an MoU has been signed between ICAR and the Asia Pacific Association of Agricultural Research Institutions (APAARI), Bangkok, Thailand. Some work plans are described below by

ICAR/DARE and other institutions (ICAR Annual Report, 2020):

- In the year 2020, a work plan for 2020-21 was signed between ICAR and The Agricultural Research Council, Pretoria, South Africa. It was signed under the MoU for Cooperation in Agricultural Research and Education.
- In the year 2017, a work plan for the period 2017-19 was signed between ICAR and The Sri Lanka Council for Agricultural Research Policy (SLCARP), Sri Lanka. It was extended till 2020 and signed under the MoU for scientific and technical cooperation, concluded on 2 July 1998.
- An MoU was signed between ICAR and IFPRI in 1988 in keeping with the desire to promote and accelerate collaborative efforts

Table 3: List of Implemented and Active Multilateral Collaboration for Agriculture Development

S.No.	Multilateral
1	ASEAN-India Cooperation in Agriculture
2	DARE / ICARs role towards cooperation in SAARC and G20
3	Network of Aquaculture Centres in Asia - Pacific
4	CABI (Centre for Agriculture and Bioscience International)
5	Asia-Pacific Association of Agricultural Research Institutions
6	International Society for Horticultural Sciences
7	International Seed Testing Association
8	United Nations Asian and Pacific Centre for Agricultural Engineering and Machinery
9	International Tropical Fruits Network
10	Indo Africa Forum Summit-I
11	Indo Africa Forum Summit-II
12	BRICS (Brazil, Russia, India, China, and South Africa)
13	Bay of Bengal Initiative for Multi Sectoral Technical and Economic Cooperation

Source: https://dare.govin, 2023

Table 4: List of Implemented and Active Bilateral Collaboration for Agriculture Development

S.No.	ASIA	AFRICA	AUSTRALIA	EUROPE	AMERICA
1	DARE-ICAR and Min. of Agriculture & Fisheries, Sultanate of Oman	ICAR-Agriculture Research Centre (ARC), Egypt	ICAR and the University of Western Australia.	ICAR and Russian Academy of Agricultural Sciences (RAAS), Moscow, Russia	ICAR and University of Saskatchewan, Canada

2	DARE in the Ministry of Agriculture and the Kingdom of Saudi Arabia	ICAR-Ethiopian Institute of Agricultural Research (EIAR)	ICAR-Landcare Research New Zealand.	ICAR and France (CIRAD/ INRA)	CAR-The Agriculture Development Fund, Govt. of Saskatchewan, Canada
3	DARE in the M/o Agriculture, India and the M/o agriculture, India and Iran	DARE-Govt. of Republic of Eritrea		DARE/ ICAR-DG (Agro), The Hague, the Netherlands	DARE and Department of Agri. Foods, Canada
4	ICAR-Nepal Agricultural Research Council (NARC), Nepal	ICAR-Golden Valley Agriculture Research Trust (GART), Zambia			ICAR and Kansas State University, Kansas, U.S.A
5	ICAR-BARC, Bangladesh	DARE-D/o Agriculture, Forestry & Fisheries (DAFF), Republic of South Africa			ICAR-Cornell University, USA
6	ICAR-CARP Sri Lanka	DARE-ICAR participating under MoU signed between Govt. of India in DoAC and the Republic of Tunisia			ICAR and INIA (Institute De investigaaones gropecurarias), Chile
7	DARE-Afghanistan	DARE-ICAR participating under MoU signed between Govt. of India in DoAC and the M/o Agriculture, Mozambique			DARE-Ecuador

8	ICAR and the Chinese Academy of Agricultural Sciences (CAAS), China	DARE-ICAR participating under MoU signed between Govt. of India in DoAC and the M/o Agriculture, Govt. of the Republic of Tanzania			ICAR-EMBRAPA, Brazil
9	M/o Agriculture, India and Ministry of Agriculture and Food Industry, Socialist Republic of Vietnam	DARE in the M/o Agriculture, India, and Ministry of Agriculture, Water & Rural Development, Namibia.			DARE-Trinidad & Tobago and the Commonwealth of Dominica).

Source: https://dare.govin , 2023

for research and training in food and agricultural policy. In light of this, on 1st May 2020, a work plan was signed between ICAR and the International Food Policy Research Institute for 2020–25. In addition to this, an MoU was signed in the year 2020 between ICAR and the Asia-Pacific Association of Agricultural Research Institutions (APAARI), Bangkok, Thailand for cooperation in agricultural research and education.

Further, DARE-ICAR is involved in bilateral cooperation for research and education in Agriculture and allied fields through MoUs and Work Plans shown in the table.

Table 5: Budget Estimates and Revised Estimates of DARE in Indian Rupees Lakhs (100000)

Items	2018–19 (Unified Budget)		2019–20 (Unified Budget)		2020–21
	Budget Estimates	Revised Estimate	Budget Estimates	Revised Estimates	Budget Estimates
International Co-operation (Minor Head) India's Membership Contribution to Commonwealth Agricultural Bureau	25	22.85	25.35	25.35	25.35

India's Membership Contribution to Consultative Group on International Agricultural Research	525.75	590	590	545	545
Asia Pacific Association of Agricultural Research Institutions	14.6	8.5	9	9	9
International Seed Testing Association, Zurich, Switzerland	4.25	4.25	4.25	4.25	4.25
International Society for Horticulture Science, Belgium	0.4	0.4	0.4	0.4	0.4

Source: Author, 2023 (Compiled from the Annual Report of DARE and ICAR)

The budget of DARE for international collaboration in the last three years has been almost constant. The details are shown in the table and it can be seen that the revised estimated budget for international cooperation and India's membership contribution to the Commonwealth Agriculture Bureau is INR 22.85 lakh (1 lakh=100,000) in the year 2018-19, slightly increasing up to INR 25.35 lakh budget estimates in the year of 2020-21. Similarly, the revised budget for India's Membership Contribution to Consultative Group on International Agricultural Research is INR 525.75 lakh in 2018-19, increasing up to INR 545 lakh budget estimates in 2020-21(Annual Report of DARE, 2020; Annual Report of ICAR, 2020).

Conclusion

Science diplomacy is playing an important role in achieving the agricultural research and development agenda. It helps to access technology for agricultural innovation and research in the country and deals with issues of climate change and sustainable development. With the help of science diplomacy, technology transfer becomes easier from the Global North to the Global South countries, including India. There are several modes of India's science diplomacy functioning i.e. bilateral programmes and multilateral initiatives with the EU, ASEAN, BRICS, G-20, IBSA, BIMSTEC, etc. It also has collaborations with international organisations such as UNESCO, TWAS, the UN Commission on Science and Technology for Development, and the OECD. For instance, under the bilateral programmes, there are joint industrial R&D funds with countries like Israel, Italy, and Canada, etc. in several sectors that facilitate innovation and science diplomacy. It is thus, a separate division of International Cooperation that works on building partnerships with other countries of the world in a multilateral and bilateral format.

In light of this, under a multilateral format, the Department of Agriculture, Cooperation and Farmers Welfare plays a role as the nodal institution in the Government of India for contact with FAO and WFP of the United Nations and also directs the department's interaction with other bodies such as G-20, BRICS, etc. Similarly, under bilateral cooperation, it covers the processing of proposals for the signing of agreements and MoUs and implements them through work plans. Besides this, it also helps to conduct meetings and exchange of human resources and knowledge sharing for furthering cooperation in the field of agriculture and allied sectors. The role of science diplomacy in the development of agricultural research can be seen in various forms. For instance, India has been a contributor and voting member of the Consultative Group on International Agricultural Research (CGIAR) for the last decades. CGIAR is a global partnership that links with an international organisation to participate in research for a food-secure future. The research deals with reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring sustainable management of natural resources.

In addition, several research projects were signed between ICAR and other international institutes such as ICRISAT, CIMMYT, and ICARDA for cooperation in the field of agriculture research and education. In this sense, ICAR is playing an important role in science diplomacy to endorse and speed up collaborative efforts across the world for research and training in food and agriculture policies. As data suggests, in the last two decades the number of MoU agreements has increased gradually, especially within Asian countries. These activities are carried out in coordination with the Ministry of External Affairs and other concerned Departments.

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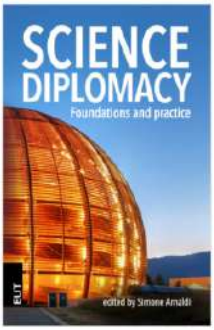
BOOK REVIEW

Science Diplomacy: Foundations And Practice



Science Diplomacy. Foundations And Practice

Edited By: **Simone Arnaldi**

Ivy Roy Sarkar*

Ivy Roy Sarkar

Whether it is in climate change negotiations, pandemic scares, security threats or sustainable development agendas, science and technology are today at the heart of international affairs. Indeed, their 'mutual influence' is variously recognised as so important and pervasive that the field should be recognised as an independent sub-discipline' within the study of international relations. Yet, there is a dearth of academic work that deals with the complex relationships between international diplomatic and scientific endeavours. Despite the long history of the relationship between science and diplomacy, the term 'science diplomacy' is a phenomenon of the 21st century. Toward the end of the Cold War, much of the focus of science diplomacy moved beyond the role of science as a bridge to diplomatic dialogue and more toward the role of science interactions as the basis for addressing key global challenges. But how can we bridge the divide and possibly 'rebalance' the encounter between the practice of 'science diplomacy' and its practitioner-driven literature? The volume ***Science Diplomacy: Foundations and Practice*** (2023), edited by Simone Arnaldi, is a comprehensive exploration of the evolving field of "Science Diplomacy".

*Fellow, RIS.

The book addresses fundamental questions, unravelling the essence of science diplomacy and why it is indispensable in addressing contemporary challenges such as climate change and geopolitical rivalries. This volume not only delves into the intricacies of science diplomacy but also raises a broader question that resonates with the current global milieu: Can speaking of 'science diplomacy' situate our attention at the crossroads of science and international relations, and spur greater appreciation for their intersections? Structured into two distinct parts, this book navigates the reader through the theoretical underpinnings and practical applications of science diplomacy.

The first part, "Foundations of Science Diplomacy," begins by delving into the theoretical constructs of science diplomacy, aiming to provide 'divergent definitions' that capture the essence of this interdisciplinary field. The three chapters meticulously dissect the components of science diplomacy, emphasising its pivotal role as a mediator between the realms of science, society, and policy. Pierre-Bruno Ruffini's chapter, as an enlightening prologue, provides a crucial historical context, emphasising that 'Science diplomacy' entered the lexicon of international relations a decade ago. Despite its decade-long presence, it remains inadequately understood, often mistaken for mere international scientific cooperation. tracing the historical evolution of 'Science Diplomacy'. By drawing on historical examples, he presents a general introduction to science diplomacy, situating it within the broader context of public policies and unveiling its various practices. Ruffini astutely identifies the main objectives pursued by states engaging in science diplomacy: attraction, cooperation, and influence. Mitchell Young's chapter amplifies the role of science diplomacy within the multi-level governance of the European Union's foreign policy, underlining significant investments made by the EU in this realm. Young critically assesses the implemented activities, delving into the current developments in EU-level science diplomacy. The chapter becomes a compelling exploration of the feasibility and organisation of a cohesive EU strategy for science diplomacy. In the quest for a cohesive EU strategy for science diplomacy, Young meticulously dissects the different levels, actors, tools, and types of power at play. In order to make sense of the EU's science diplomacy, it is, therefore, necessary to dig into the four dimensions that structure the EU's practices of science diplomacy. Rooted in principles of multilateralism and global solidarity, the EU utilises science diplomacy to respond effectively to a myriad of global challenges. Young's analysis underscores the multiplicity inherent in each dimension, portraying science diplomacy as a dynamic and adaptable tool for the EU.

In defining science diplomacy, the next chapter by Arnaldi delves into the classic definition by the Royal Society and the American Association for the Advancement of Science (AAAS), which categorises science diplomacy activities into three groups: scientific advice to foreign policy (science in diplomacy), facilitation of international scientific cooperation (diplomacy for science), and the use of scientific cooperation to improve international relations among states (science for diplomacy). However, Arnaldi critiques this definition for its inadequate acknowledgment of the political and power dimensions inherent in science diplomacy, emphasising the importance of recognising national interests in these initiatives. Drawing on four models of science policy—linear, demand pull, systemic, and transformative—Arnaldi assesses their impact on how science-society relations are perceived.

The Second part of the book meticulously offers profound insights and multifaceted perspectives on science diplomacy "in action". It commences with Mounir Ghirbi's introduction of the 5+5 Dialogue Initiative on Research, Innovation, and Higher Education, emphasising its role in fostering collaboration between the EU Member countries and the Arab Maghreb countries. Ghirbi outlines the initiative's dedication to address shared challenges, underlining the importance of research, innovation, and higher education in the development and prosperity of the Mediterranean region. It sees scientific cooperation as a means to strengthen cross-border alliances in the sustainable blue economy sector, facilitating the exchange of knowledge, goods, and services, as well as fostering the circulation of talents between the two shores of the Mediterranean.

Alessandro Lombardo, Senior officer at the Executive Secretariat of the Central European Initiative (CEI), in the next chapter, provides a thorough exploration of the CEI's journey in science diplomacy, detailing its historical roots, practical initiatives, and the multilateral objectives it seeks to achieve in bridging the worlds of science and diplomacy. Lombardo explores the dual purpose of both science diplomacy and regional cooperation, highlighting their contributions to the consolidation of multilateral relations and the pursuit of national interests. He also notes that science diplomacy within the CEI has pursued multilateral goals. These include translating scientific research into knowledge for informed policy-making, organising effective dialogues between the scientific and diplomatic realms, professionalising relations between these communities, and fostering collaboration to address shared transnational challenges.

In Peter F. McGrath's chapter, he sheds light on The World Academy of Sciences' (TWAS) impactful initiatives aimed at promoting international mobility among scientists, creating awareness about the influence of scientific research on SDGs, particularly in areas such as food and nutrition security, safe drinking water, and sanitation, and fostering civic engagement within the research community. The chapter emphasises the importance of supporting research in Low- and Middle-income Countries (LMICs) to address global challenges effectively. The chapter underscores the instrumental role of TWAS and scientific institutions in and around Trieste, funded by the Government of Italy, in serving as soft power instruments through science diplomacy to enhance Italy's credibility and influence on the global stage.

After exploring the genesis and development of SESAME (Syncrotron-light for Experimental Science and Applications in the Middle East), a multidisciplinary research laboratory in Jordan, Giorgio Paolucci's chapter highlights the diplomatic potential of SESAME in fostering collaboration among countries facing geopolitical tensions, showcasing its role as an instrument of soft power and a catalyst for dialogue between diverse cultures and experiences. Paolucci highlights SESAME as more than just a regional laboratory; it is a unique developmental opportunity poised to play a pivotal role in the scientific, technical, and economic advancement of the Middle East. The versatility of synchrotron light research, applicable across a spectrum of scientific domains from atomic physics to life sciences and materials science to archaeometry, allows researchers from various disciplines to collaborate and develop innovative ideas and methodologies. What sets SESAME apart is its function as an open space, where countries that may typically struggle to find common ground come together.

In conclusion, Science Diplomacy: Foundations and Practice is a collaborative effort between the Department of Political and Social Sciences of the University of Trieste, the Executive Secretariat of the Central European Initiative, and the Autonomous Region of Friuli Venezia Giulia that addresses a significant gap in introductory materials on science diplomacy, especially for an Italian audience. From formulating 'divergent definitions' to establishing foundational principles, from mitigating geopolitical crises to achieving SDG goals, from showcasing science-based laboratories to advocating for multilateral cooperation, these chapters have an admirable range, variety and scope. In aiming to recover areas that have long been either systematically repressed or under-represented for disciplinary reasons, and in wanting readers to pay attention for reasons that are socially, economically or environmentally urgent, the chapters strongly appear as manifestos and calls to bring the field of Science Diplomacy close to the research arena. This book certainly, is a valuable resource for scholars, policymakers, and students interested in the intersection of science and diplomacy, offering profound insights into the evolving landscape of international collaboration and understanding.

G20: Call for Papers

G20 is gaining importance as a global platform for articulation of economic, social and development issues, opportunities, concerns and challenges that the world is confronting now. Over the years, G20 has witnessed a significant broadening of its agenda into several facets of development. India is going to assume G20 presidency in 2022 which would be important not only for the country but also for other developing countries for meeting the Sustainable Development Goals and achieving an inclusive society. India can leverage this opportunity to help identify G20 the suitable priority areas of development and contribute to its rise as an effective global platform.

In that spirit, Research and Information System for Developing Countries (RIS), a leading policy research institution based in New Delhi, has launched a publication called G20 Digest to generate informed debate and promote research and dissemination on G20 and related issues. This bi-monthly publication covers short articles of 3000 to 4000 words covering policy perspectives, reflections on past and current commitments and proposals on various topics and sectors of interest to G20 countries and its possible ramifications on world economy along with interviews of important personalities and news commentaries.

The Digest offers promising opportunities for academics, policy makers, diplomats and young scholars for greater outreach to the readers through different international networks that RIS and peer institutions in other G20 countries have developed over the years. The interested authors may find more information about the Digest and submission guidelines on the web link: **http://www.ris.org.in/journals-n-newsletters/G20-Digest.**

Guidelines for Authors

1. Submissions should contain institutional affiliation and contact details of author(s), including email address, contact number, etc. Manuscripts should be prepared in MS-Word version, using double spacing. The text of manuscripts, particularly full length articles and essays may range between 4,000- 4,500 words. Whereas, book reviews/event report shall range between 1,000-15,00 words.

2. In-text referencing should be embedded in the anthropological style, for example '(Hirschman 1961)' or '(Lakshman 1989:125)' (Note: Page numbers in the text are necessary only if the cited portion is a direct quote). Footnotes are required, as per the discussions in the paper/article.

3. Use's' in '-ise' '-isation' words; e.g., 'civilise', 'organisation'. Use British spellings rather than American spellings. Thus, 'labour' not 'labor'. Use figures (rather than word) for quantities and exact measurements including per centages (2 per cent, 3 km, 36 years old, etc.). In general descriptions, numbers below 10 should be spelt out in words. Use fuller forms for numbers and dates— for example 1980-88, pp. 200-202 and pp. 178-84. Specific dates should be cited in the form June 2, 2004. Decades and centuries may be spelt out, for example 'the eighties', 'the twentieth century', etc.

Referencing Style: References cited in the manuscript and prepared as per the Harvard style of referencing and to be appended at the end of the manuscript. They must be typed in double space, and should be arranged in alphabetical order by the surname of the first author. In case more than one work by the same author(s) is cited, then arrange them chronologically by year of publication.

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About FISD

As part of its ongoing research studies on Science &Technology and Innovation (STI), RIS together with the National Institute of Advanced Studies (NIAS), Bengaluru is implementing a major project on Science Diplomacy, supported by the Department of Science and Technology. The programme was launched on 7 May 2018 at New Delhi. The Forum for Indian Science Diplomacy (FISD), under the RIS–NIAS Science Diplomacy Programme, envisages harnessing science diplomacy in areas of critical importance for national development and S&T cooperation.

The key objective of the FISD is to realise the potential of Science Diplomacy by various means, including Capacity building in science diplomacy, developing networks and Science diplomacy for strategic thinking. It aims to leverage the strengths and expertise of Indian Diaspora working in the field of S&T to help the nation meet its agenda in some select S&T sectors.

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