Identifying New Partnerships for Innovation: Governance and Policy Challenges

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Abstract

Science, technology, and innovation (STI) are critical to national competitiveness, security, domestic and international policy, governance, politics, economic growth, culture, and human well-being. One course of action is to only collaborate with known, established partners. But this approach comes with the risk of missing out on the next "up and coming" player, losing the beneficial products that could arise if collaboration had been established earlier. Newcomers are nations that are developing competency and breakthroughs in specific disciplines but have not yet attained global recognition for their expertise and capacity. This paper explores the practical policy and governance challenges associated with identifying and partnering with lesser-known countries, with the goal of providing an advantage to both newcomer nations and more established partners.

Keywords: Innovation, Technology Policy, International Relations, Diplomacy

1. What are "Emerging Technologies"?

A plethora of words are used when discussing technology and innovation, causing much confusion and inconsistent use of terminology.

First, there is no universally accepted definition of a "novel technology". The term "novel technology" (or "innovation") is often described in Schumpertian language, insinuating a new technological paradigm and trajectory. When describing technologies and innovations, "novel" is commonly used in the fields of medicine, health, and biotechnology, particularly when describing new treatments, products, and procedures.

Second, "enabling" technology, unlike "novel", is a term that describes a unique type of technology that helps support further developments within a field, altering the way people do things. In this way, enabling technologies enhance, simplify, or otherwise modify existing materials or technologies for some intended beneficial purpose. But, many disparate uses of the term occur across sub-specialties. For example, enabling technology is sometimes discussed in medical ethics as "a general designation of technology that alleviates the impact of disease or disability" [1].

Third, "high-tech" is applied to industry, occupations, and products [2]. The Congressional Office of Technology Assessment originally defined high-tech firms as "those engaged in the design, development, and introduction of new products and/or innovation manufacturing processes through the systematic application of scientific and technical knowledge [3]…[that use] state-of-the-art techniques…devote a large proportion of expenditures to research and development…[and] have a high proportion of scientific, technical and engineering personnel" [2]. The North American Industry Classification System (NAICS), the US government's official industry classification, does not define high-tech industries [4]. The OECD classifies global manufacturing activities and industries into different levels of technology intensity [5] (see **Figure 1**). High-technology versus low-technology industries are identified by looking at the direct research and development (R&D) input and output. High-tech industries had high R&D investment, high levels of value added from such investment, and high levels of R&D production.

The U.S. Bureau of Labor Statistics attempted to identify high-tech industries by using occupational data of STEM workers [4, 6]. They went further than the OECD and differentiated between manufacturing and service industries (see **Figure 2**), but only for the U.S. context. Moreover, high-technology occupations "are scientific, engineering, and technician occupations" that need "an in-depth knowledge of the theories and principles of science, engineering, and mathematics underlying technology [typically] acquired through specialized post-high school education in some field of technology…from a vocational certificate or an associate's degree to a doctorate" [4]. Governments and supranational organizations have more clearly defined what is and is not "high tech"; therefore, high tech often includes established industries and occupations. This means that newer technologies (i.e. emerging technologies) might not be included under high-tech. For example, in 2005, biotechnology and nanotechnology were not listed as high-tech industries because they were not identified as official industries in NAICS [7] – this is despite their recurring status as emerging technologies by international organizations such as the World Economic Forum [8].

Fourth, a "disruptive" technology (i.e. often used interchangeably with "disruptive innovation") is either one that (a) displaces an established technology and shakes up the industry or (b) is a ground-breaking product that creates a completely new industry. Disruptive technology stems from the theory of disruptive innovation which views disruption as "a process whereby a smaller company with fewer resources is able to successfully challenge established incumbent businesses" [9]. Disruptive technologies aren't just new scientific solutions. They are new products sold to the least profitable segment of a market using a non-traditional business model from those of incumbents (i.e. Apple, Netflix, Uber).

Fifth, "technological emergence" is "a cyclic process in highly creative scientific networks that demonstrates qualitative novelty, qualitative synergy, trend irregularity, high functionality, and continuity aspects in a specified time frame" [10], leading to new technologies and innovations. "Technological breakthroughs" (e.g. breakthrough inventions) is yet another concept discussed in the literature. Again, there are numerous definitions for the term. Commonly, a breakthrough innovation is defined as "any creative and original action by individuals or project teams that enables firms to capture at least temporary monopoly profits or that results in a significant increase in market share" [11]. Alternatively, breakthrough innovations are also the "creation of a new platform or business domain that has a high impact on current or new markets in terms of offering wholly new benefits on the firm through the expansion into new markets and technology domains, increased revenues, and ultimately increased profits" [12].

Broadly, emerging technologies fall into eight umbrella groups that often overlap: processors, biotechnology and bioelectronics, transducers, robotics, networks, nanotechnology, quantum computing, and all 'other' digital technologies. These technologies change over time as science progresses. The OECD groups the top 40 emerging technologies into 4 domains (1) digital, (2) biotechnologies, (3) energy and environment, and (4) advanced materials [13] (see **Figure 3**).

2. Overview of Governance and Policy for Newcomers

2.1. International Relations and Science, Technology, and Innovation

From industry to energy, technology can help provide new benefits to human welfare, rapidly changing and adapting to meet societal needs. But, new technologies bring with them new hazards, risks, and uncertainties [14]. Governments are charged with the responsibility to establish new policies, regulations, and possible investments that will maximize the benefits and minimize the risks of new technologies. Moreover, science, technology and innovation all directly impact security, defense, and the economy, making them important to foreign policy and global trade relationships. The geo-political and economic impact of new scientific discoveries is growing, requiring nuanced and complex multi-level governance. Supranational organizations like the OECD and United Nations have tried to spearhead initiatives that measure the impact of technology and innovation on economic development to find solutions for global problems like poverty. Science and technology are critical to improve diplomatic and political aims, as well as, local skills and domestic capabilities [15].

The five key types of actors involved at the intersection of international relations and science, technology and innovation are: (1) national or multi-national firms, (2) individuals and the public, (3) universities and public research centers, (4) governments (i.e. individuals, organizations, and nations), and (5) national defense and military organizations [16]. Every actor has their own goals, leading to tensions when they differ on political, cultural, and diplomatic issues, with conflicts hindering existing and future international research collaborations.

One solution to overcome such obstacles is the use of diplomatic resources (i.e. embassy personnel) to spearhead a bottom-up research effort. This idea of "science for diplomacy" (and "diplomacy for science") helps benefit diplomatic aims and achieve political and technological objectives that are otherwise difficult to accomplish [17]. Science provides a common language and a culture of collaboration. The goal of science in diplomacy is to inform foreign policy objectives with scientific advice. The goal of diplomacy for science is to facilitate international science cooperation, especially for high-cost, high-risk international scientific projects. "Science for diplomacy" uses science cooperation to improve international relations between countries, especially when strained relations exist [18]. Diplomats and scientists work together (i.e. science attaché) to advance their respective and shared goals through bilateral and multilateral ties between states [15, 19-21].

Three obstacles often limit the growth of international science cooperation and collaborations. First, scientists and diplomats have disparate career paths and incentives. Second, diplomacy has a top-down hierarchy, but the nature of science is bottom-up. Third, government officials may not understand the benefit of scientific and technical collaborations for domestic affairs [15]. Possible solutions to overcome such structural limitations are (1) promoting collaborations between scientists and diplomats to solve policy problems in joint forums, (2) including scientific experts in formal governmental advisory boards, and (3) increasing the number of diplomats with intermediate to advanced backgrounds in science, technology, and innovations [15, 20].

2.2. Policy and Governance Challenges in International Science Policy with Newcomers

The exponential production of new technologies "threatens to outpace the ability of societies and policymakers to adapt to the changes they create" [22]. Technological change can systematically impact social and institutional change, but the reverse is also possible. Many emerging technologies can provide opportunities, solutions, and benefits to society that are better, cheaper, faster, scalable, and easier to use. New forms of governance are necessary to better guide international scientific collaborations and technology governance (e.g. "the process of exercising political, economic, and administrative authority in the development, diffusions and operation of technology in societies" [13]). However, governance challenges can prevent many of these benefits from coming into fruition.

Effective partners need to have a high willingness to engage in international collaboration (i.e. "openness"), typically measured by a country's diplomatic and economic openness. For example, the willingness of a country to trade goods relates to their willingness to also exchange ideas as seen between the United States and Japan. Countries with high levels of openness benefit from a "technology spillover" from other nations. Another criterion for determining a quality research partner is a country's level of intellectual protections. Strong intellectual protections signify a well-built research structure that innovates more. Thus, the two key challenges when determining whether to engage with newcomers are: (1) early, accurate identification, and (2) effective, sustainable engagement.

Governance and policy challenges relative to international scientific engagement center upon two core tasks: (a) fostering standards and protocols to execute surveys and data gathering/analysis of the international scientific landscape, and (b) developing algorithms and processes for engagement of potential scientific partners in a manner that accounts for their unique economic, political, and social characteristics. These twin challenges represent the bulk of any nation's policy goals within international scientific engagement [15].

For the former, a clear set of policies that mandate the passive and active collection and analysis of development trends and data regarding scientific potential and performance within a given country are likely mandatory for a nation to effectively develop and leverage scientific collaboration in a meaningful and beneficial manner. One common program held by countries with demonstrated success in international scientific engagement includes a science attaché program, where scientific experts are stationed at embassies of potential trade and research partners in order to ease the process of scientific investment and bilateral cooperation [20, 23]. More senior government leadership (i.e. chief technology advisor) can help steer a nation's bilateral and multilateral scientific engagement opportunities [24]. Such institutional mechanisms enable both a passive surveillance of potential collaboration opportunities abroad, as well as a simplified means of enabling direct collaboration through knowledgeable stakeholders and clear bilateral agreements.

Another need is consistent data collection and analysis of science and technology development within various potential partner countries. Government agencies and ministries with a strict responsibility of surveying and analyzing scientific trends are best suited towards conducting annual reviews of scientific growth within a given nation. Such reviews should include future projections regarding the rate of scientific growth (i.e. publication rate, citation rate, number of new Ph.D.'s, etc.), as well as, political and economic drivers influencing the growth or decline of a given scientific discipline within that country (i.e. the institution of new policies or triggering events that incentivize or disincentivize the development of a specific technology).

For the latter, once potential newcomers have been identified, concerns remain regarding how best to engage them in a shared and mutually-beneficial platform. Social, governance, and cultural differences and challenges can frame or determine whether newcomer engagement is practical or sustainable over time. Science does not exist in a vacuum, but instead is framed by the value and importance that societies place upon it.

Many developing nations currently do not have the necessary pre-requisites to take advantage of the global economy [25]. These countries face challenges in the form of human capital, infrastructure and logistics such as roads, ports, and airports, governance regimes that are not conducive to business and innovation, and inadequate capital and labor markets [25]. While such limitations may be prohibitive in terms of their potential as a future scientific power, in some circumstances a directed course of investment could unlock the nation's innovative potential within one or more sectors.

On the other side of the investment dilemma, developing nations face the challenge of trying to appear attractive to foreign investors, especially in finding ways to reduce perceived project investment risks. Developing nations need to appear commercially attractive for outside investments, maximizing financial returns while minimizing risks. Investment projects may include risks related to the size of the market, technological feasibility, skills of the workforce, intellectual property protections, or regulations on repatriation of profits [26].

Ultimately, engagement is defined by multiple strategies: (a) political incentives/bilateral trade agreements with the other country, (b) investment into the country and its scientific sector, or (c) incentivizing select individuals within the foreign country to relocate to your nation for purposes of research and development. Strategies chosen in this regard are defined on a case-by-case basis relative to the target nation's general stance (i.e. friendly or unfriendly), their relative capacity for scientific research and development, the institutional, social, and cultural values, and appreciation for such research.

2.3. Challenges

According to the OECD, the growth in nationalism, protectionism, and parochialism around the globe is putting existing and future international science collaborations at risk [27]. Many challenges to international science diplomacy bifurcate into public versus private sector concerns. Each of these sectors have unique challenges that directly impact the other. In particular, finding solutions to both sets of problems is critical for successfully identifying and engaging with newcomer countries in the future.

The public sector faces unique challenges for science diplomacy and engagement of newcomers in emerging technology. The first set of challenges are political and institutional. Broader geopolitical interests can politicize science and negatively impact the quality of technology developed and innovation output produced. There is a risk of abusing "science for diplomacy" for the sake of establishing coveted diplomatic relationships. Additionally, geopolitical interests can hinder a nation's ability to engage with newcomers and establish strong scientific collaborations, especially if the two nations have tense political relationships with one another.

The second set of challenges revolve around security and competitiveness. One of the most recent challenges in international science diplomacy is mutual respect for intellectual property and national patent laws. Growing fears of technology theft and science espionage can hamper future initiatives for global research collaborations. Ensuring that newcomer countries abide by the more stringent patent laws of established technology leaders is not always easy. Since technology and innovation directly impacts a countries overall economic growth and development, there is a strong push to make sure that intellectual property is respected across international borders. Concerns of economic competition in technology development environments can also make collaboration more difficult. Newcomer countries often have strong desires to grow economically more competitive with their emerging technologies, but they often lack the resources to fully develop their innovations into tangible products with useful applications.

With the rise of emerging technologies, there are concerns about the dual-use nature of technology. Specifically, the European Union defines dual use technologies as “items, including software and technology, which can be used for both civil and military purposes” [28]. Organizations like the International Traffic in Arms Regulation (ITAR) exist to restrict and control the transfer of military and defense technologies. The U.S. Department of Commerce lists dual-use items (i.e. equipment, assemblies, components, materials, software, technology) which heavily overlap with many emerging technologies (see **Figure 4)**.

The private sector has its own challenges, often relating to marketplace dynamics. The cost of entry into research (especially for emerging technologies) is high. There are large fixed costs for equipment, instruments, and labor. This prevents smaller businesses, particularly those from low- and middle-income countries, from entering the global economy as quickly as businesses in developed countries with a large amount of investment capital. Lack of visibility in the global economy may make it more difficult to spot newcomers. Moreover, some newcomer countries may find it difficult to keep a new research program or technology economically viable. There are also proprietary concerns about intellectual property and ownership of technology. While science is collaborative, the private sector has strong incentives to keep technological advances and innovations private under trade secret laws.

Insurance is important in order to attract investors for new businesses, research and innovative product development [29]. Insurance is critical to overcome risk as a barrier to innovation. New technologies have many risks associated with the development, production, and distribution processes of turning a scientific novelty into a viable product [29]. Without adequate insurers, innovation and technology will stagnate. This is particularly important in newcomer countries and their markets where insurance companies may not operate, may have unsustainably high premiums, or are hesitant to insure product development due to the numerous uncertainties and lack of precedent.

There are also cultural limitations in scientific collaboration and technological development. For example, some technologies are socially unacceptable (i.e. stem cell research). Religion and cultural norms make certain sciences or subjects’ taboo. Certain emerging technologies will not receive investment or scientific investment in countries where such technologies or their applications are considered taboo.

Last, academic institutions often transcend both the public and private sector. First and foremost, academia wants to build and maintain successful institutions. Part of this endeavor is the creation of research programs that produce high quality knowledge output. However, universities are constrained by steep costs, labor shortages, and time limitations. Universities also house expensive, prototypical, rare, and/or complex instruments (i.e. spectrometers, telescopes, semiconductor fabs, reactors, etc.) and information resources (i.e. libraries, access to journal subscriptions, extensive archives, etc.) which are not easily transferable or shared. Therefore, academic institutions and research centers are critical in enabling emerging technologies to develop and in continuing to invent new technologies and innovations. Universities and research centers are often hubs of innovation that bring together the top minds in smaller countries.

3. Existing Incentives and Engagement Mechanisms

3.1. Incentives

The four core incentives that exist are (1) funding incentives, (2) commerce incentives, (3) hard access incentives, and (4) soft access incentives (see **Figure 5**). The two main types of funding incentives are *direct* incentives like legislative laws and passed policies or *competitive* incentives like setting up a fund to compete for a pool of money. Commerce incentives include trade agreements, tariffs, subsidies, and tax breaks. Hard access incentives relate to facilities and instruments, as well as, strict rules, laws and regulations.

Soft access incentives relate to diplomatic and consular benefits. For example, countries want to have better diplomatic relationships with the United States, so they are more willing to establish partnerships in order to gain access to key diplomat networks. There are also incentives in providing access when setting up a small business that can enable innovation and technology (i.e. the United States' SBIR program). Educational incentives to acquire talented international students in STEM can also be leveraged, but only if combined with mechanisms to enter the country (i.e. work visas, prolonged student visas, etc.) so that they can legally participate in the US workforce.

3.2. Engagement

Engagement can occur either through 'soft' or 'hard' law. Most engagement mechanisms are examples of 'soft law'—non-legally binding agreements that look like legal obligations (i.e. written exchange of promises, standards, consortiums, etc.). These soft mechanisms are often industry-led or -driven (i.e. the International Organization for Standardization). Alternatively, there are also 'hard law'—i.e. formal rules, treaties, relationships, and agreements–types of engagement mechanisms. Hard engagement mechanisms are either (1) bilateral or (2) multilateral.

Bilateral engagement mechanisms are state-to-state relationships (see **Figure 6**). These begin with a 'dialogue' that can eventually progress towards a formal agreement or treaty. Institutional precedent and current practice can guide such engagement mechanisms. Precedent may create obstacles in identifying newcomer countries where existing relationships or prior mechanisms of engagement do not exist. For example, international treaties exist that regulate the use of Antarctica, space, and oceans. Many multinational agreements exist to provide access to resources such as telescopes. Additionally, there are countries that are not part of multinational agreements, but they are important partners in scientific and engineering research (i.e. Switzerland and the Large Hadron Collider). Such countries can also have bilateral agreements between universities or small research group collaborations.

Multilateral engagements are a growing necessity due to the global and multidimensional nature of technological challenges, wide distribution of research experts and facilities around the world, large amount of data generated, and increasing costs of conducting research [17]. Unlike bilateral mechanisms, multilateral mechanisms involve two or more countries that all equally govern an established agreement, creating "skin in the game" incentives. It is an expansive platform so other countries can join over time, reducing cost burdens for massive global initiatives.

4. Addressing Challenges & Gaps in Existing Policy

According to the National Research Council, research relationships work effectively when (1) there is focus on priority areas that were mutually agreed upon across all collaborating countries, (2) researchers possess cultural awareness and local language skills, (3) include educational and capacity-building programs, (4) share data, and (5) build on well-established collaborative activities [17]. The governance of emerging technologies requires governments to balance private sector needs and market dynamics with the public good and democratic legitimacy [13, 30].

Science does not always provide quick, easy answers. Emerging technologies are developing at a rapid pace, but evidence is constantly changing and their uncertainties and risks are unknown. Policymakers and key government decisionmakers need to collaborate with trained scientists to prepare for the unexpected. The National Research Council noted a few important barriers to effective global scientific collaboration that are relevant for handling newcomer partners [17]:

- unclear motivations and restrictions on mobility
- weak public-private partnerships
- inflexibility in U.S. government program (e.g. "short-termism" among policymakers)
- lack of effective incentives
- lack of human capital and infrastructure in partner countries (i.e. developing and newcomer countries)
- lack of a unified voice in the science community
- lack of accountability and "broken promises"

Using existing databases can help find social, political, and cultural data on newcomer countries to understand outside factors that may influence what science is developed, the internal sustainability of research developments, and the stability of the political environment for long-term diplomatic relationships. The World Bank and OECD are two organizations that already collect such data through their openness ratings and democracy indexes. When identifying suitable newcomers to partner with, existing country priorities for science and economics can help signal what their governments support politically and financially.

In order to effectively identify newcomers in emerging technologies, governments will need to learn to identify non-traditional signals. Non-traditional signals can come from academic institutions, trends in funding, specific technologies, and the corporate and private sector. Academia and universities provide a wealth of non-traditional signals that can help policymakers identify good newcomers to partner with. Patterns and clustering of academic hiring can help establish a network of scientific expertise in specific fields. Also, patterns of university strategic developments can showcase long-term institutional commitments to specific themes in research investments. University-to-university relations can hint at countries that are already vetted as potential partners.

In summary, international science and innovation partnerships can provide tremendous value to nations but require the proper incentives and engagement strategies to be successful. Practical takeaways for policymakers and practitioners engaged in international research include the following:

- Remember that science doesn't exist in a vacuum. When identifying potential partners, it is important to consider the cultural context and national-level characteristics including openness and IP protections.

- Engagements can involve a number of specific activities, including trade agreements, investments, and relocation of particular experts.
- Four core incentives exist when structuring collaboration partnerships, including (1) funding incentives, (2) commerce incentives, (3) hard access incentives, and (4) soft access incentives.
- Maintaining a robust science attaché program can facilitate scientific collaboration and innovation.

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Figure 1. OECD Classification of Technology Intensity

<u>High-technology Industries</u> • Aircraft and spacecraft • Pharmaceuticals • Office, accounting, and computing machinery • Radio, TV, and communications equipment • Medical, precision, and optical instruments	<u>Medium-high-technology Industries</u> • Electrical machinery and apparatus • Motor vehicles, trailers, and semi-trailers • Chemicals excluding pharmaceuticals • Railroad equipment and transport equipment • Machinery and equipment
<u>Medium-low-technology Industries</u> • Building and repairing of ships and boats • Rubber and plastic products • Coke, refined petroleum products, and nuclear fuel • Other non-metallic mineral products • Basic metals and fabricated metal products	<u>Low-technology Industries</u> • Manufacturing, recycling • Wood, pulp, paper products, printing and publishing • Food products, beverages, and tobacco • Textiles, textile products, leather, and footwear

Source: Adapted from [5]

Figure 2. US Bureau of Labor Statistics Classification of the "High-Tech" Industry

Main Industry	Specific Sub-Industries
Manufacturing Industry	▪ Petroleum and coal products ▪ Basic chemical ▪ Resin, synthetic rubber, and artificial synthetic fibers and filaments ▪ Pharmaceutical and medicine ▪ Industrial machinery ▪ Commercial and service industry machinery manufacturing, including digital camera ▪ Engine, turbine, and power transmission equipment ▪ Other general purpose machinery ▪ Computer and peripheral equipment manufacturing, excluding digital camera ▪ Communications equipment ▪ Audio and video equipment ▪ Semiconductor and other electronic component ▪ Navigational, measuring, electromedical, and control instruments ▪ Manufacturing and reproducing magnetic and optical media ▪ Electrical equipment manufacturing ▪ Aerospace product and parts
Service Industry	▪ Pipeline Transportation ▪ Software publishers ▪ Wired telecommunication carriers ▪ Wireless telecommunication carriers (except satellite) ▪ Satellite, telecommunications resellers, and all other telecommunications ▪ Data processing, hosting, and related services ▪ Other information services ▪ Architectural, engineering, and related services ▪ Computer systems design and related services ▪ Management, scientific, and technical consulting services ▪ Scientific research and development services ▪ Management of companies and enterprises
Other Industry	▪ Oil and gas extraction ▪ Electric power generation, transmission, and distribution ▪ State government education ▪ Federal government

Source: Adapted from [4]

Figure 3. OECD's List of Key Emerging Technologies

The key digital technologies are: • Cloud computing • Blockchain • Photonics and light technologies • Robotics • Modeling simulation and gaming • Quantum computing • Grid computing • Artificial intelligence (AI) • Internet of Things (IoT) • Big data analytics	**The key advanced materials technologies are:** • Engineered nanomaterials • Functional materials • Nano-devices • Additive manufacturing • Carbon nanotubes and graphene
The key biotechnologies are: • Bioinformatics • Personalized medicine • Health monitoring technology • Medical and bioimaging • Regenerative medicine and tissue engineering • Stem cells • Biocatalysts • Synthetic biology • Neurotechnologies • Biochips and biosensors	**The key energy and environment technologies are:** • Smart grids • Micro and nano satellites • Precision agriculture • Biofuels • Fuel cells • Power microgeneration • Autonomous vehicles • Drones • Advanced energy storage technologies • Electric vehicles • Carbon capture and storage • Wind turbine technologies • Photovoltaics • Hydrogen energy • Marine and tidal power technologies

Source: Adapted from [13]

Figure 4. Dual-Use Technologies & Emerging Technologies

Dual-Use Technologies	Emerging Technologies
• Nuclear • Materials, chemicals, microorganisms, and toxins • Materials processing • Electronics • Computers • Telecommunications and information security • Lasers and sensors • Navigation and avionics • Marine • Propulsion systems, space vehicles, and related requipment	• Energy capture, storage, and transmission • Biotechnologies • Neurotechnologies • Advanced materials and nanomaterials • 3D printing • Artificial intelligence and robotics • New computing technologies • Virtual and augmented realities • Blockchain and distributed ledger • Ubiquitous linked sensors • Geoengineering • Space technologies

Source: U.S. Department of Commerce, Commerce Control List (15 CFR 774)

Figure 5. List of Incentives for International Scientific Collaboration

Type of Incentives	Examples of Incentives
Funding Incentives	▪ Competitive (i.e. Grants) ▪ Direct (i.e. funding through federal appropriations, direct R&D)
Commerce Incentives	▪ Free Trade agreements (i.e. NAFTA) ▪ Tax credits and incentives for investment (i.e. Singapore) ▪ Small Business programs, incubators, accelerators
Access Incentives	▪ Visa access & Employment (i.e. H1B Program) ▪ Equipment and Facilities (i.e. telescopes, particle accelerator, unique geographic biodiversity, International Space Station) ▪ Science Diplomacy (i.e. attaché programs, Embassy Science Fellow)

Figure 6. AAAS Typology of Immersive Science & Technology Engagement Mechanisms

Model	Target Group	Duration	Purpose
Fellowships	▪ Graduate STEM students ▪ Early to mid-career scientists ▪ Policymakers	1 year + (full time)	▪ Learn ways science impacts policy ▪ Contribute unique skill sets and expertise to policymaking ▪ Establish contacts, foster relationships, build networks ▪ Increase comfort of policymakers in working with scientists ▪ Expose scientists to policy processes and culture ▪ Explore policy-related career paths ▪ Transition to civil service
Internships	▪ Undergraduate to graduate STEM students ▪ Early-career STEM graduates	3 months – 1 year (full time)	▪ Learn ways science impacts policy ▪ Develop awareness of policy processes and culture ▪ Establish contacts, foster relationships, build networks ▪ Explore career options
Pairing Schemes (i.e., science attaches)	▪ Early-career to senior scientists ▪ Policymakers	1-2 weeks per year	▪ Improve mutual understanding ▪ Establish contacts, foster relationships, build networks
Details and Rotations (i.e., Embassy Science Fellows)	▪ Early-career to senior scientists ▪ Civil servants	2-4 years (full time)	▪ Deepen understanding of policy processes and culture ▪ Contribute expertise to specific issues or projects ▪ Establish contacts, foster relationships, build networks ▪ Transition to civil service

Source: Adapted from [31]