SCIENCE DIPLOMACY

Inaugural Issue

SCIENCE DIPLOMACY PERSPECTIVES

March 2022

Preface

It is a pleasure for me to introduce this inaugural Issue on '***Science Diplomacy Perspectives***'. The Issue comes at a time when the world is gradually recovering from the COVID-19 pandemic. The recovery comes on the back of extraordinary scientific and sociotechnical achievements in developing vaccines and devising emergency health security measures. This marks an epoch which underscores the value of creating a facilitating interface between science, policy, and society. Scientists and Diplomats, by virtue of their profession, act at the interface of innovation and negotiation – a pathway for societal progress. This interdisciplinary engagement has the capacity to deliver truly sustainable solutions for global challenges such as food security, climate change and protection of the global commons.

This Issue is an effort to showcase academic efforts, practitioner experiences and thematic exchanges between interdisciplinary stakeholders. At a time when technological advancements are outpacing regulatory structures and broader societal discourse, science diplomacy provides a perfect platform for multistakeholder dialogue. Pakistan's approach to scientific innovation has been driven by its desire to achieve socio-economic development. Some articles in the issue touch upon our 'Atoms for Sustainable Development' pledge, through which organizations such as the Pakistan Atomic Energy Commission are actively harnessing nuclear energy to attain various targets under the theme of Sustainable Development Goals.

Similarly, some articles expand upon the theme of emerging technologies and the necessity for multilateral engagement to ensure equitable access and reduce silos between various stakeholders. This Issue also includes an event report on 'Lahore Science Mela', a heartening Science Popularization initiative centred on engaging youth on the wonders of science.

I want to congratulate and thank all authors & editors for contributing to this pioneering initiative. Furthermore, the editorial and peer review support provided by the OIC Standing Committee on Scientific & Technological Collaboration (COMSTECH) and the Particle Team at LUMS is also commendable.

We plan to make 'Science Diplomacy Perspectives' a permanent publication platform for science diplomacy experts, practitioners and enthusiasts.

Sohail Mahmood
Foreign Secretary

Editorial

The Ministry of Foreign Affairs' Science Diplomacy Division is actively working on building pathways that connect the often-siloed stakeholders of innovation and diplomacy. Science diplomacy as a niche practice has allowed a new avenue for scientists, diplomats, and policy makers to bridge gaps, create synergies and ideate inclusive models of growth. Through this Issue on 'Science Diplomacy Perspectives', we are providing a scholarly template to academics and practitioners for pitching interdisciplinary ideas, providing relevant science advice and highlighting key issues related to the science-policy-society interface.

In this pioneering attempt, we were pleased with the diversity and quantity of articles received. As the contours of science diplomacy are still being explored and its definitional typologies are also under active discussion, we have tried to provide a South-South voice to the landscape. Our featured articles range from themes such as new and emerging technologies, science advice mechanisms, regulatory aspects, science popularization and academic networking.

The field of science diplomacy is advancing rapidly, from academic and practitioners' perspective. It is vital to reconcile both approaches to create substantive outcomes. In some of the articles included in the Issue, the role of science diplomacy in providing a rubric for regulation of emerging technologies has been discussed. Such an approach is adding to the application of science diplomacy in the multilateral governance of science.

In many ways, the intersection of technology and international relations has shaped the economic and political progress of many countries. Some articles in the issue discuss the impact of this convergence on nuclear and cyber technologies.

Many research institutions in Pakistan have benefitted from international collaborations. We have also featured articles covering this crucial aspect of this scholarly connection and the tangible impact that it has created.

I hope this Issue provides an initial impetus for creating a regular interdisciplinary and science diplomacy driven platform for scientists, diplomats, and policymakers. Subsequent to this publication, we are making 'Science Diplomacy Perspectives' a regular publishing platform.

Mohammad Kamran Akhtar
Director General (Science Diplomacy)

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New and Emerging Technologies

Fusion Science Diplomacy: Way Forward

Dr. Shahid Hussain (Director, Pakistan Tokamak Plasma Research Institute, Pakistan Atomic Energy Commission)

Nuclear Fusion

Fusion is the most extensively studied idea for a low-carbon primary energy source. Fusion energy could provide a future source of non-carbon emitting electricity generation for the world and could play a vital role in the global transition to a net zero carbon emission electricity infrastructure. It can be a new and ultimate source that can deliver base-load electricity and complement intermittent low-carbon energy sources that are already being exploited.

Nuclear fusion is the process by which two light atoms merging to form products with a total mass less than that of the original atoms. The mass difference is converted into energy according to Einstein's famous formula. The fusion reaction that is easiest to exploit is between the hydrogen isotopes, deuterium, and tritium, with the reaction products being helium nuclei and neutrons. However, a temperature in the range of millions of degrees is required for the fusion reaction to take place.

The fact that nuclear fusion could take place to produce energy had been known since 1930, when scientists believed that the fusion was the source of energy at the Sun, and the stars. At the Sun, gravity keeps the reactants together so that the fusion reaction can continue. Scientists have for the past many decades been talking about fusion-based power plants on earth. But the earth's gravitational force is not so large because of its much smaller mass.

On the earth, many ideas have been conceived and several devices have been built to produce a sustained fusion reaction. The one, which has worked better than others, was to electronically heat the charged particle, and confine these charged particles (in a so-called plasma state) to the desired geometry by applying strong magnetic fields around it.

After different types of machines had been developed, the Russian machines, branded Tokamak, gained worldwide acceptability. Tokamak is the device which holds the promise of providing limitless, sustainable, and clean energy to the world through nuclear fusion. It has a configuration of a doughnut in which high currents of the order of Mega Amperes are produced through transformer action and magnetic fields (~Tesla) are used to confine and stabilize the plasma. Over the years, Tokamak devices have shown steady progress towards the desired values of plasma parameters appropriate for reactor environment. Many countries most notably Japan, USA, UK, Russia, and China have built several Tokamaks improving the performance of controlled fusion devices. Some recent devices are JT60 (Japan), DIII-D (USA), JET (UK), Russia (T-15) and EAST (China).

International Scenario

The world's largest and most ambitious fusion reactor "ITER- International Thermonuclear Experimental Reactor" is under construction in France with cost around USD 23 billion. Seven partners (China, European Union, India, Japan, Russia, South Korea, and USA), representing more than half the world's population, are working hard with all resources and expertise to ensure the success of ITER. The EU is sharing 45.6% of the cost while every other member had to pay around 9% or around one billion USD in-kind. All seven ITER member states have strong domestic tokamak based fusion program and have built several Tokamaks. Australia, Canada, Kazakhstan and Principality of Monaco are associated with ITER as non-party. The first operation of ITER is scheduled in the year 2025. After the successful operation of ITER in 2025, a breakthrough is anticipated to occur by 2030.

The next step to ITER is the demonstration power plant “DEMO”. Every member of ITER is free to design its own DEMO (demonstration power plant) as there is no collective agreement on DEMO. The DEMO will lead fusion into its industrial era, beginning operations in the early 2035, and putting fusion power into the grid as early as 2040.

A race for the construction of demonstration reactor has already been started among the ITER member states. The partner countries are undertaking large efforts to capitalize on their involvement and develop their own nuclear fusion capabilities to generate electricity.

India who is the member of "ITER" since 2005 is spending huge sum of money for its domestic Tokamak fusion program. India has plans to build a medium size "fusion reactor" by the year 2027, DEMO fusion reactor by the year 2037 and a commercial fusion power plant by the year 2050.

China is rushing towards earliest development of its DEMO reactor (CFETR). European Union is working on “A roadmap to the realization of fusion energy” for bringing Fusion Electricity to the grid and a consortium “EURO fusion” is setup for it.

Recently, the National Academies of Sciences, Engineering, and Medicine (US) have jointly submitted a report to the US Department of Energy (DOE) to lead the world in fusion and to make an impact on the transition to a low-carbon emission electrical system by 2050. This report presents a strategic plan for the design, construction, and operation of a fusion pilot plant with the objective of producing electricity in the 2035-2040 timeframe.

The supporting facilities for ITER and DEMO like IFMIF-DONES (for material testing under harsh reactor environment) and a world's largest Computational Simulation Centre (for integrated modelling of reactor plasma) are being established.

Strong interest from the private sector motivates development of a fusion pilot plant, as companies like Tokamak Energy (UK), General Fusion (Canada), Lockheed Martin (USA), and several others seek to lead the way towards decarbonizing and modernizing the national's energy system. The private companies are more optimistic about the earlier (in 2030s) success of small fusion power plant up to 100 MW.

Fusion Technology in Pakistan

Realizing the importance of fusion technology, Pakistan Atomic Energy Commission (PAEC) established a research group named "National Tokamak Fusion Program - NTFP" in 2007 consisting of plasma physicists and engineers throughout the country. The aim was to establish strong foundation of tokamak fusion technology and to train human resource for future fusion power reactor.

This group has established a small Tokamak facility for training of manpower. A series of three Glass Tokamaks and two Metal Tokamaks has been developed with indigenous efforts, which are small in size, but have put Pakistan on the world map of Tokamaks. The experimental results from these devices have been published in the form of papers (50) in the reputed international journals. Also, liaison has been established with the Institute of Plasma Physics Chinese Academy of Sciences (ASIPP) China, which is a member of ITER-organization.

The up gradation of this small facility to a medium size tokamak is under development at the institute and a small laboratory infrastructure is also under construction to accommodate the new device.

Recently, to expand the scope of R&D activities, the tokamak program (NTFP) has been renamed as "Pakistan Tokamak Plasma Research Institute – PTPRI". In spite of lot of financial constraints, the institute is working at its best to cope up with the rapid changes around the world in the area of nuclear fusion and to fill the technological gap of decades to bring Pakistan at some respectable international level.

Links with the international tokamak community are being expanded to get benefits from the latest technological developments. Further, extensive training programs are being initiated on world known Tokamak devices so that considerable human resource may be developed in this important technological area as the technology may get restricted soon.

It is also being tried to include the cooperation in Tokamak fusion technology on the agenda of "CPEC" so that the technological cooperation may be extended between "Belt and Road" countries and also to become official partner of Chinese Demo reactor "CFETR - China Fusion Engineering Test Reactor". The platforms of IAEA and CERN will be utilized to interact ITER as these two big organizations have technological cooperation agreements with ITER.

Developing a fusion power plant require expertise in a wide range of cutting-edge technologies and skills from researchers and engineers in industry, national laboratories, and universities. Therefore, multi-dimensional programs will be initiated on national level to get maximum trained manpower for future fusion power plant of Pakistan. Also, there are many spinoffs /applications while working at these high-end technologies of fusion power reactor that will benefit strategic as well as open sectors of the country. All out efforts are being made to develop Tokamak fusion power technology in Pakistan.

The subject of fusion energy is extremely relevant to the "**Vision-2025**" of the government of Pakistan as it lays emphasis on exploration of renewable resources for overcoming the power shortage and energy crises in Pakistan. Nuclear fusion has potential as alternative energy source and may be the ultimate source of energy for future.

Further, the cutting-edge technologies involved in fusion power reactor will complement to the GoP's (Government of Pakistan) vision of achieving "**Knowledge based economy**" and will boost the industrial infrastructure of the country.

Fusion power has potential to create Socio-Economic Impact in the country as energy and power generation is the need of the hour for Pakistan. Although, the available sources are contributing to the energy/power requirements but are still not sufficient to meet the growing demands. Power generation through Nuclear Fusion should be given significant importance as the same will have good synergy affect i.e. greater output with lesser input and also provide ample opportunities in employment generation, support to industry, creation of economic activities, self-sufficiency in power generation, and economic stability for the country.

Small Tokamak Facility at PTPRI - PAEC

Impact of New and Emerging Technologies – a Science Diplomacy Perspective

Dr. Syed Javaid Khurshid, Senior Research Fellow, Center for International Strategic Studies

Science diplomacy is defined as international cooperation in scientific fields to foster communication and cooperation among people of diverse nations aiming at promoting global peace, prosperity, and stability. It provides an alternate channel other than normal diplomatic contracts for communication among nations, through discussion of international issues by also looking at them from a scientific angle.

Though the term science diplomacy, the term emerged in the 21st Century, it has been closely related to State's political system for centuries. The combination of science and diplomacy has helped in addressing regional and global issues and has achieved a number of successes in furthering peace, security, and prosperity in the past. Science diplomacy in earnest got started after world war-II on the issue of nuclear weapons. The scientists of the USSR, USA, and Europe got deeply involved with the diplomats on nuclear safety and security issues. The exchange of views between Soviet and western scientists helped the two sides to understand the stand of the other side on nuclear arms control and other related issues. A good example is US-Cuba diplomatic relations. First, the scientists of the two countries engaged in marine sciences in Carrabin, and the health threats from infectious diseases. Then in 2014, AAAS sent a high-level scientific delegation to Cuba and signed an agreement with the Caribbean Academy of Sciences to pursue active collaboration which helped in the establishment of diplomatic relations in 2015.

Only a few institutions in the world are presently actively engaged in science diplomacy and international dialogue on science. These include the Centre of Science Diplomacy of the American Association for the Advancement of Science (AAAS), The International Network for Government Science Advice (INGSA), Science Diplomacy, Tufts University, International Institute for Applied System Analysis (IIASA), the International Science Council (ISC), Third world Academy of Sciences (TWAS) and Diplomacy program of OPCW, Besides these institutions, The Science Diplomacy Thematic Network, University of Arctic and International Academies of Sciences are also working towards this end. Two other organizations comprising of the world's science academies are created for advising, the Inter-Academy Panel focused on capacity building for Science Academies and Inter-Academy Council on science advice. These two institutes are now combined in the Inter-Academy Partnership (IAP). It facilitates the regional and global meetings of science academies at the request of the United Nations on a range of issues. There are some multinational projects like the Centre for European Nuclear Research (CERN), International Thermonuclear Experimental Reactor (ITER), and Synchrotron Light for Experimental Science Applications in the Middle East (SESAME) which are an example of successful science diplomacy between many countries.

These days three issues are considered very important in Science Diplomacy. The first is the mitigation of Weapons of Mass Destruction (WMDs), the second is to achieve poverty alleviation by achieving the UN's Sustainable Development Goals (SDGs) and the third is international cooperation to achieve the optimum benefit from the new and emerging technologies.

A) Science diplomacy can play a very effective role in controlling, implementing regulations, and finally eliminating WMDs. Here we have to remember that science is the foundation of all developments of WMDs, and that only the scientists have the knowledge and the expertise to devise the methods of monitoring and verification for reducing the ill effects of WMDs. For example, the establishing of the Comprehensive Test Ban Treaty, nonproliferation, and countering nuclear terrorism. International science cooperation can create a basis for trust and confidence which can play a key role in eliminating WMDs. Many scientists, diplomats, politicians, and NGOs are working in science diplomacy to increase security and mutual trust among nations.
B) Another important area where science diplomacy is playing a very effective role is in achieving the UN's 17 SDGs in improving living conditions and the health of billions of people living in different geographical regions on our planet. The better part of the 20th Century saw tremendous technological growth and its living conditions are now quite different as compared to in the 1970s. One major example is the way the internet has changed our lives in the last 20 years. It is expected that these changes are going to be more drastic in the 21st century. Human beings, therefore, have to make choices between the technologies which are better for humanity and those that may look attractive

but may be harmful in the long run. All Sustainable Development Goals (SDGs) have to be achieved for a better life and they need scientific diplomacy and cooperation in various scientific fields worldwide, especially in power generation, agriculture, and health.

The importance of science diplomacy in improving health indicators has been proved in dealing with challenges such as HIV/AIDS in Africa, and the fight against new infectious diseases of Ebola, Zika, MERS, and SARS, and now in 2019, the coronavirus-19 pandemic. Through coordinated global response and international programs based on scientific research and technology combined with international cooperation, we have been able to save much of humanity from death or serious diseases.

In 2016, Paris Agreement on Climate Change was another success of science diplomacy through Intergovernmental Panel on Climate Change (IPCC). The reports of IPCC not only urged governments to adopt current Scientific knowledge on climate change but also to formulate their policies to guide them about what could be done scientifically about mitigation, and adaptation options.

C) The third and most important area is of the New Emerging Technologies and their Impact worldwide. They are the technologies whose full potential is still unrealized. Breakthrough on emerging technologies such as Artificial Intelligence (AI), Cyber Security, 3D laser printing, Drones, Biometrics, Nanotechnology has already been made and some more may be on the way. These technologies are contemporary advances and innovations in various fields of science and technology.

The potential benefits of emerging technologies are enormous and well known but their harmful effects may also be enormous too. All the emerging technologies are dual use. The puzzling question is how we can only get benefits and save humanity from the harmful effects of these technologies. The answer is in science diplomacy, which is coined to cover all these problems.

1) Artificial intelligence is the feat achieved by computer sciences, which may become the core component of all software of the future. Artificial intelligence is about building machines that can think and act intelligently depending upon algorithms. This gives an opportunity but also creates a threat. It can be used for

both defensive and offensive purposes. This technology besides bringing prosperity will require a high level of security. Artificial Intelligence has become very popular soon after it was made available for public use because it has the potential to reduce human work and bring convenience and efficiency to our lives. AI effects on people and society are becoming very visible as progress is taking place in this field. Computer-based vision, speech recognition, and natural language processing, autonomous vehicles, and organizing the cities, as well as home service robots, and AI-based services in education, entertainment, and public safety as some AI benefits. Since AI has the potential to be integrated into virtually every product and service across cyberspace, geospacer, and space to make them intelligent. This evolving cognitive ability fundamentally changes the security landscape for humanity. This is going to impact badly the job markets throughout the world in the years to come.

AI is also of dual use, of which three are prominent for weaponizing. i) Computer vision does image and video analysis to survey physical space and respond to behavioral patterns and enables militaries to integrate computer vision software in a security camera. At the same time, also enables tracking the movements of suspicious people, targets on the battlefield, and detecting mines. ii) It enables Language Processing making the possible real-time translation, summarization, and information extraction. The most important aspect of AI technology is that anyone can create an algorithm that can have dual usage. iii) AI-generated 3-D images representing people places, and things. Artificial Intelligence is among many other emerging technologies which will change the face of warfare in the years to come.

2) Cyber networking has become a vital part of government systems of many advanced countries whereas other countries are also increasing the role of computer networking in their systems. While it is making running government systems more efficient and shared rapid decisions can be taken by computer networking, but it is also a security challenge. Many countries suffered cyber-attacks. In the future, business concerns, as well as nations, may increase their efforts to bring harm to their rivals through cyber-attacks. Data protection, therefore, will be of fundamental importance. Cybercrimes may originate in one

state and target another. The issue needs to be handled through science diplomacy. Two terms are very important in this context. Cyber security is the readiness of a country to efficient use of computer networks and cyber defense is the ability to protect itself from such cyber-attacks. Cyber technology can be used as a cyber weapon as well Cyber technology is already being used for controlling drones and certain autonomous weapons. In the future, however computers warfare may include remote-controlled chemical and biological weapons. Cyber technology will increase the precision of strike capability but at the same time, it will increase the militarization of space. Ministry of Foreign affairs should hire science diplomats or cyber diplomats to handle cyber security issues in consultation with other states.

3) Advancement in biological sciences is a challenging area that also demands a focus on biosecurity and mitigating the proliferation of biological weapons. Developments in Biogenetic Engineering are being made in a very vast area. When applied correctly it helps in making progress in a number of SDGs directly, such as those pertaining to agriculture, biotechnology, and health. Gene and Genome editing on a range of biological species have revolutionized our approach to human health and the treatment of diseases. To save the world stringent criteria for clinical trials of human germline cells need to be evolved with consensus among states. Some recent developments in biotechnology need to be kept under strict observation because while holding a tremendous promise to benefit human beings it also increases the possibilities of misuse, as biological weapons. The science diplomacy covering assessment mechanisms, strengthening detection procedures, prevention, response to biological incidents globally, and following BTWC can be very effective in controlling its misuse and using the biological sciences for the benefit of mankind.

4) 3-D Laser Printing: 3-D laser printers create a 3-D printed object from a digital file. The 3-D printers are doing many beneficial things for humanity, but at the same time, this technology can be used to create very dangerous things which can threaten the security implications of these and other neighboring countries. The technology is fast, flexible, and cost-effective and might one day print custom-made heart valves and enable astronauts to print their tools while in space, On

the other hand, it can be used to produce guns parts and other military equipment. There are also many areas to carefully watch. Besides possible security threats, it is possible that 3-D laser printing might be able to produce some consumer goods in the future and will cause a threat to the industry and job market. The 3-D printers combined with artificial intelligence could make it easier for individuals to build nuclear, chemical, and biological weapons. Science diplomacy can persuade nations to avoid going on this path.

5) Drones Technology is cheap and comparatively easier to master. It has been used to benefit in a lot of ways such as for landscaping, water scanning, spraying pesticides on the crops but at the same time, they can be used for spraying harmful chemicals and biological materials. Drones have been used in many conflicts in the last 10 years. Syria, Ukraine, and Libya are the major examples. Drones are now a part of the arsenals of many countries Turkey has made a lot of progress in drone technology and made tremendous progress using science diplomacy against Israel. Drones' proliferation is increasing rapidly and their use affecting security. Their use in Afghanistan and Yemen has serious implications for the security of these and other neighboring countries. Indians put a display on their drone's swarm's deployment capability on Army Day Parade in 2019. Pakistan too is reportedly acquiring drone technology for military use. In this evolving security environment between India and Pakistan, it is very important to ensure that drones are not misused and or their use may not trigger an escalation in the hostilities between the two rival countries.

6) In the Power Sector besides using different types of nuclear reactors for reducing CO_2 emission the safety can be increased but then the digitalizing energy sector also increases the risk of cyber-attacks and related security issues. Though the policymakers and power reactor operators are fighting to keep the threat away. The threat was highlighted in 2010 by the use of malicious code called Worm specifically formulated to target the inner systems of power plants. It is thought that this malware infected more than 15,000 computers worldwide. The safety and security of nuclear facilities from cyber-attacks is an essential and very important aspect that should be one of the areas of focus of science diplomacy.

7) In 1996, nanoscience was beginning to be recognized as an important new scientific field and the US allocated $ 1 billion as a Nanotechnology initiative. Nanotechnology is playing an important role in improving many technologies and other industries, including information technology, security, medicine, transportation, energy, food safety, textile, and environmental science. Nanotechnology materials can be converted into stronger, lighter, more reactive, better electric conductors. The surface treatment of fabrics can make them lightweight, resistant to wrinkling, and staining. Light weighting of vehicles and air crafts would lead to saving of fuel in cars and trucks, etc. The nanoparticles probes are being used in clinical investigations, giving better therapeutic results in cancer and other diseases. Nanotechnology is also used in the diagnosis and treatment of atherosclerosis, and delivering medication to cancer cells, that minimizes the risk of damage to healthy tissues. In the food industry, this technology is vastly used to increase global food production. Nanoparticles can also be very dangerous as they are of the same dimensions as biological molecules and can penetrate the human cell. As these ultrafine particles can also spread toxicity easily in the body, the main dual use of nanotechnology at present can be in chemical weapons by nanoformulation and delivering them to the body effectively and rapidly.

The societal impacts of new technologies such as AI, Cyber, Drones can be easily identified but very difficult to predict or measure. Acquiring new technologies is always beneficial but also has the potential danger to humans, and global safety and security.

Science Diplomacy between countries can help to share the good results for mutual benefit and to mitigate the bad effects to humanity. Science diplomacy, it is revealing that global compromises have been achieved in areas of arms control, poverty reduction. global health, science innovation, and relation of some countries where scientists have played an important role. Scientists may be good in their area of technical expertise but relations between states also need a different set of experts. Diplomats, and scientists, therefore, should be working together to make the world a more peaceful place for humanity. Science diplomacy can achieve the required goals of restriction, collaboration, and cooperation in the future. Science diplomacy has enormous potential for the building, handling, and solving of contentious issues between states and to reduce the sharp divide between northern and southern hemispheres, the east and west, and between developing and developed countries. As a scientist, I strongly believe that science is a universal language that can overcome differences among nationalities, races, ethnicities, and religions. Our mission should be to make World a better place for future generations. Science diplomacy can help developing countries access scientific resources and promote their involvement in regional and global research.

Recommendations:

1. A National Scientific Commission (NSC) should be constituted, comprising of 20 prominent scientists, with representation from the provinces, Ministry of Foreign Affairs, Ministry of Interior, and Ministry of IT.
2. Pakistan Academy of Sciences should be the guiding body of Scientific Diplomacy executed through the help of MOFA & MOST.
3. Pakistan Academy of Science with the help of NSC should finalize the 6-8 fields for Scientific Diplomacy.
4. Pakistan Academy of Science with the help of NSC should formulate the guiding principles of scientific research for all the scientific organizations & Universities for Research and Development.
5. More international institutions worldwide should be developed in cutting edge technologies to handle global problems jointly such as ocean governance, water, energy, and understanding of volcanos i.e., Synchrotron light for Experimental Science and Applications in the Middle East (SESAME).
6. Pakistan should figure out areas where it needs help and areas where it can provide help to activate science diplomacy
7. NSC, PAS & MOFA should develop a strategy for global scientific collaboration & cooperation leading to science diplomacy.
8. These bodies should look to increase & upgrade the scientific activities within the country to the international level to increase cooperation & collaboration.

Further Reading

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Emerging technologies: an unavoidable topic for developing countries

Dr. Laura A Galvis (Postdoctoral Researcher, Institut NeuroMyogene)

The recent GESDA Science Diplomacy Summit brought forth an engaging discussion around some of the technologies expected to shape human societies in the near future. Its Science Breakthrough Radar offers insights and potential timelines into some of the hottest topics in science: human gene editing, quantum computing, artificial intelligence, lifespan extension, among others. Topics that stimulate our imagination and make us think about the science fiction stories we read growing up. However, how relevant are these emerging technologies to someone who does not have access to electricity or safe drinking water? How should low-income countries allocate resources on these topics? What will be the cost of ignoring this evolving reality? Responding to current challenges like climate change and food insecurity without the help of these innovations is impossible. However, these technologies can also expand the breach between rich and poor countries. Contrary to previous technological jumps, it is imperative for countries to prepare for the benefits and divisions these emerging technologies will entail, regardless of their income.

Between-countries inequality has been growing since the industrial revolution, when technological differences strongly impacted human wellbeing, economics and social structures. Today, 85% of inequality is accounted by between-countries inequality (rather than within-country), implying that the biggest determinant of your access to opportunities will be the country where you are born (1). The economic advantages brought forth by technology provide more resources for research and development, which in turn increase the gap with less-developed countries, feeding a cycle of growing inequalities. However, technology *per se* cannot be blamed for the social disparities that have arisen since the industrial revolution. They are rather linked to unequal distribution, profit concentration and restricted access, and as such are the result of economic and political decisions (2,3). With this new wave of frontier technologies already changing our work habits and our personal interactions, it would be naïve to believe that the effects that these technologies will have on inequality will be different to those observed with all other technological jumps in the last 200 years.

In the same way that governments use taxes and redistribution policies to reduce wealth inequalities, limiting disparities created or exacerbated by these frontier technologies while maximising their benefits needs to be guided by social studies and implemented through policy and legislation. The fast pace of our current technological progress also implies that these policies need to be flexible or reactive enough to avoid becoming outdated as the technology evolves. Contrary to what most scientist like to believe, science is political, and scientific development should not be disjoined from social, economic and cultural discourse. As mentioned by Habets *et al*, understanding science is not enough to know how to best govern it (4). Understanding how society will react to certain technology and how to present it may be crucial to its success and its integration in society. For example, Japan and other East Asian countries, where sociotechnical imaginaries of robots are more positive, have incorporated this technology more readily than western societies accustomed to the mostly dystopian vision of science fiction and the clear distinctions between nature and technology (5). In the case of genetically modified organisms (GMO), a negative perception in the general population has hindered its development and implementation, despite the many benefits it could offer (6,7). The importance of early social studies in the effect of these frontier technologies will be critical to avoid a situation like the GMO fiasco. Additionally, each technology impacts inequality differently, and its potential effects must be anticipated to design effective policies. For example, automation is threatening the loss of jobs, while gene editing is feared to generate biological inequalities. The response to each needs to be tailored.

For developing countries, the challenge ahead is double. Engaging in these new technologies needs to be coupled to reducing the existing technological gaps. There is no one-for-all solution. Like in evolution, the success of a strategy cannot be determined independently from the context. Some countries in Eastern Asia have done a magnificent job in technologically catching up during the last 50 years (1,8). The Technology and Innovation Report 2021 highlighted countries that are pulling above their weight in technology readiness based on their GDP per capita (1). They have done so through policy, incentives, investment, and industrialization (1). A multifaceted and dynamic strategy is probably needed.

Shared and open access resources to tackle common problems or improve mutual areas of interest may be part of the answer to the limited resources these countries have for research and technology. A bigger involvement of non-state actors may counterbalance, or at least diminish, the negative effects of political instability. Non-state actors, like the Organization for Women in Science for the Developing World, can also provide spaces for capacity-building, and resource-sharing, to surmount traditional barriers of access (9). An integrative strategy with the scientific diaspora could enrich national research capacities and avoid brain drain. Public campaigns could place science and technology as central players in the national identity. Universal internet access could facilitate skill development and engagement with these emerging technologies.

Perhaps we should take our hats off to all the developing countries out there, tasked with the arduous challenge of catching up in their deficits with less resources and less stability, while actively contributing to the technological frontier in order to retain some power in a playing field dominated by big performers. Despite the difficulties that developing countries face, failure to integrate emerging technologies will only guarantee that the inequality breach will keep on growing and that R&D remains oriented to solving the problems of developed countries.

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7. Jiang, K., Anderton, B. N., Ronald, P. C., & Barnett, G. A. (2018). Semantic network analysis reveals opposing online representations of the search term "GMO". *Global Challenges*, *2*(1), 1700082.
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9. Bonilla, K., Cabrera, J., Calles-Minero, C., Torres-Atencio, I., Aquino, K., Renderos, D., & Alonzo, M. (2021). Participation in Communities of Women Scientists in Central America: Implications From the Science Diplomacy Perspective. *Frontiers in research metrics and analytics*, 27.

Technological Challenges in the Way of Nuclear Risks Reduction and Strategic Stability in South Asia

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Introduction

According to the theory of nuclear deterrence, a state acquires nuclear weapons in self-defense if its territorial integrity and sovereignty come under attack. Nuclear weapons serve as a shield for a state having conventional asymmetries against its adversary[1]. However, emerging technologies are questioning the efficacy of nuclear deterrence. The unregulated military use of cyber technology, Artificial Intelligence (AI), deep-fakes, quantum computing, hypersonic missiles, and advanced ballistic-missiles defense systems are questioning the credibility of nuclear deterrence, resultantly increasing the risks of inadvertent or intentional use of nuclear weapons[2]. Rebecca Hersman has attributed this situation as "*Wormhole Escalation*". According to her, *"emerging technologies have created openings (Wormholes) in the fabric of nuclear deterrence that may compel competing nations into an intentional or inadvertent sub-conventional or strategic level of conflict"*. Emerging technologies have also changed the concept of the "stability-instability" paradox and Kahn's 44 rungs escalation ladder by making the patterns of escalation non-linear and unpredictable. Now states are using emerging technologies in place of surrogates and proxies to target their adversaries below the nuclear threshold. Moreover, the precision and lethality of digital weapons are blurring the lines between the conflicts at sub-conventional, conventional, and strategic levels and creating a challenging situation for nuclear risks reduction[3].

Emerging technologies are also threatening the strategic stability of South Asia. In all such scenarios, the presence of three nuclear-armed neighbors i.e., India, China, and Pakistan, intensifying conventional and nuclear arms race, are the factors posing serious challenges for the strategic stability of the region. The nuclear history of the region reveals that Pakistan's nuclear program is purely defensive and it was forced to adopt a nuclear path. Since the nuclearization of South Asia in 1974, nuclear weapons-free South Asia has remained the cornerstone of Pakistan's nuclear diplomacy. Since 1947, the dispute of Jammu & Kashmir which caused wars continues to be the mother of all disputes between both countries[4]. However, the recent developments like growing violence in Afghanistan, border tensions between India and China, and the growing militarization of the Indian Ocean are not a good omen for regional stability. These developments should be analyzed in the context of Indian military modernization and its growing belligerence which has further accentuated after declaring it a Net-Security provider in the Indian Ocean Region[5].

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[1] Caitlin Talmadge, "Emerging Technology and Intra-War Escalation Risks: Evidence from the Cold War, Implications for Today," *Journal of Strategic Studies* 42, no. 6 (2019): 864–87.

[2] Keir A. Lieber and Daryl G. Press, "The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence," *International Security* 41, no. 4 (April 1, 2017): 9–49, https://doi.org/10.1162/ISEC_a_00273.

[3] Rebecca Hersman, "Wormhole Escalation in the New Nuclear Age (Summer 2020)," 2020, https://doi.org/10.26153/TSW/10220.

[4] Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb* (Stanford, California: Stanford Security Studies An Imprint of Standford University Press, 2012), p. 95.

[5] Shishir Upadhyaya, "Maritime Security Cooperation in the Indian Ocean Region: Assessment of India's Maritime Strategy to Be the Regional 'Net Security Provider,'" n.d., 337.

2019's Indian testing of anti-satellite weapon (ASAT), the test of Hypersonic Technology Demonstrator Vehicle (HSTDV), acquisition of modern anti-ballistic missile defense systems, induction of combat unmanned aerial vehicles, have further heightened the nuclear risks for the region.

This paper has been divided into five portions. The first portion discusses the concept of nuclear risk reduction (NRR), its history, and different agreements concluded by the NWS. The second portion outlines the types of new and emerging technologies which are threatening strategic stability. The third part traces the nuclear history of South Asia, broad contours Pakistan's nuclear diplomacy and the CBMs taken by both countries over time. The fourth part has been dedicated to the study of threats of the military use of emerging technologies specific to South Asia and the fifth part explores the measures which could help mitigate the risks posed by the emerging technologies.

1. What is Nuclear Risk Reduction (NRR): A Historical Perspective

NRR means reducing the risks of inadvertent or intentional use of nuclear weapons. The concept of NRR is quite broad which entails several measures such as the physical safety of nuclear weapons, reducing the dangers of accidental use, de-alerting of nuclear weapons, measures against the proliferation of nuclear weapons to terrorists and non-state actors, securing nuclear command, control and communication (NC3) infrastructure and establishing communication channels at military and diplomatic levels[6].

There could be several possible scenarios during which a country may use nuclear weapons, nevertheless, for better understanding, Wilfred Wan divides those possible situations into the following four categories[7]:

Doctrinal Use	Use of nuclear weapons as per declared policies.
Escalatory Use	Refers to the use of nuclear weapons in a situation when a crisis and crosses certain thresholds.
Unauthorized Use	Unauthorized use by a non-state actor by using some stolen or lost nuclear device
Accidental Use	Refers to the launch of a nuclear missile because of human or technical error.

The intellectual base of the existing NRR concepts dates back to the cold war era. The Cuban missile crisis of 1962 is considered a watershed event in the nuclear history of the world which brought the United States and the Soviet Union close to nuclear war. The fears of another nuclear apocalypse after 1945's nuclear bombing of Japan, compelled the nuclear weapons states (NWS) and other regional nuclear powers to resort to different risk

[6] B. Roberts, "Major Power Rivalry and Nuclear Risk Reduction: Perspectives From Russia, China, and the United States" (Lawrence Livermore National Lab.(LLNL), Livermore, CA (United States), 2020).

[7] The United Nations Institute for Disarmament Research and Wilfred Wan, "Nuclear Risk Reduction: A Framework for Analysis" (The United Nations Institute for Disarmament Research, June 28, 2019), https://doi.org/10.37559/WMD/19/NRR01.

reduction measures[8]. The following table contains the list of nuclear risk reduction agreements made over time[9][10]:

Year	Agreement
1963	US-Soviet Union Nuclear Hotline Agreement
1966	French-Soviet Hotline Agreement
1967	Britain-Soviet Hotline Agreement
1973	US-Soviet Union Agreement to Remove Dangers of Nuclear War
1987	US-Soviet Agreement on the establishment of nuclear risk reduction centers (NRRCs)
1996	China-Russia Hotline Agreement
1998	US-China Hotline Agreement
2004	India-Pakistan Nuclear Hotlines Agreement
2010	India-China Hotline Agreement

However, today the emerging technologies are responsible for aggravating the risks of confrontation or a nuclear war as well. Technological advancements in the fields of cyber-space, AI, quantum computing, weaponization of outer space, and hypersonic missile technologies are raising the bar of strategic uncertainty and may trigger a crisis or even nuclear war. Emerging technologies have changed the traditional concepts of warfare by introducing non-linear and less predictable pathways to escalation, resultantly adding more challenges for crisis management. They have further made the security environment more contested by empowering the small regional powers like Iran and North Korea to challenge the strategic warfare capabilities of global powers. In reality, disruptive digital technologies have challenged the traditional ways of thinking about escalation and stability[11].

2. Impact of Emerging Technologies on the Nuclear Risks

Before discussing the adverse impacts of emerging technologies on strategic stability and NRR measures, it is better to get a definitional understanding of emerging technologies, their different types, and impacts on strategic stability.

2.1. Defining the Emerging Technologies

Emerging Technologies can be defined as those new technologies which are currently being developed or will be developed in the coming five to ten years and are characterized by novelty, and the ability to play a key role in socio-economic development[12]. In March 2020, NATO published a report entitled "Science & Technology Trends: 2020-2040" which defines emerging technologies as *'technologies with expectations*

[8] Wilfred Wan, "Nuclear Risk Reduction: Looking Back, Moving Forward, and the Role of NATO," 2020.

[9] "Hotline Agreements | Arms Control Association," accessed August 7, 2021, https://www.armscontrol.org/factsheets/Hotlines.

[10] "Nuclear Risk Reduction Centers," U.S. Department of State, accessed August 7, 2021, //2009-2017.state.gov/t/isn/5179.htm.

[11] Hersman, "Wormhole Escalation in the New Nuclear Age (Summer 2020)."

[12] Marina Favaro, "Weapons of Mass Distortion: A New Approach to Emerging Technologies, Risk Reduction, and the Global Nuclear Order," June 2021, 32.

to get mature by 2020-2040, not widely in use currently and whose impacts on defense and security are still unknown'. In the same document NATO has also defined Disruptive Technologies as *'those technologies or scientific discoveries that are expected to affect NATO defense, security or enterprise functions in the period 2020-2040'*[13]. Furthermore, Marina Favaro identifies three challenges associated with emerging technologies. Firstly, the emerging technologies are originating from the private sector, resultantly diminishing the role of the government to control them, secondly, the pace of technological production is so fast that public policy practitioners are unable to regulate them and thirdly, despite the fact the nuclear risk is increasing, yet both NWS and NNWS are unable to reach on consensus on the regulations on emerging technologies[14].

2.2. Types of Disruptive Emerging Technologies

The recently published report of Kings College London identifies the following emerging technologies having the potential to undermine strategic stability[15]:

- AI-Powered Cyber Operations
- AI for ISR (Intelligence, Surveillance, and Reconnaissance)
- Deep-Fake Technology
- Hypersonic Missiles
- Swarm Robots
- Satellite Jamming and spoofing
- Kinetic Anti-Satellite (ASAT) Capabilities
- Directed Energy Weapons

2.3. How Disruptive Emerging Technologies Harm Strategic Stability?

Following are some prominent emerging technologies having the potential to aggravate the risks of nuclear confrontation.

2.3.1. Cyber-Attacks

The incidents like the 2019 cyber-attack against the Kudankulam nuclear power plant in India and the recent Colonial fuel pipeline in the USA, SolarWinds hacks, and revelations about the Project Pegasus are a stark reminder of the grim reality that cyberspace has become an arena of military confrontation[16].

The rising tide of cyber-attacks targeting critical infrastructures might push the states towards the inadvertent of deliberate use of nuclear weapons. Any nuclear power can't compromise on its nuclear deterrence and the reliability of its NC3 infrastructure. Any cyber-attack directed against the NC3 system could become a legit reason for a nuclear response. The Global Zero Commission on Nuclear Risk Reduction has also predicted the

[13] "190422-ST_Tech_Trends_Report_2020-2040.Pdf," accessed August 3, 2021, https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf.

[14] Ibid.

[15] Ibid.

[16] Allegra Hobbs, "The Colonial Pipeline Hack: Exposing Vulnerabilities in US Cybersecurity," 2021.

possibility of jamming the early warning systems, breaching firewalls and air-gaps networks, and transmitting false launch orders or even nuclear weapons, by the hackers[17].

Even an air-gapped network could become a victim of a cyber-attack and hackers may get access to sensitive information, corrupt critical data, or cause physical damage to the infrastructure. In this regard, the most pertinent example will be of Stuxnet worm attack which targeted the SCADA (supervisory control and data acquisition) system of Iranian nuclear facilities in Natanz in 2010 and severely damaged the centrifuges used for uranium enrichment. The success of the Stuxnet attack was a turning point in the history of cyber-warfare which inspired other nations to resort to cyber means. Hackers can also Jam the air-defense system of a country. The same happened in the past in 2007 during Operation Orchard, when Israeli airstrikes destroyed the Syrian nuclear reactor in 2007 by hacking into the Syrian air-defense system[18].

Moreover, the fears of cyber-attacks against non-military targets such as national power grids, water supply systems, financial and banking systems, and other critical infrastructure have compelled the countries to re-adjust their nuclear doctrines and lowering of the nuclear threshold. In this regard, the US Nuclear Posture Review (NPR) of 2018 clearly states that the US may retaliate by nuclear means in case of non-nuclear strategic attacks[19].

As of today, United States, Russia, United Kingdom, China, Iran, and DPRK all have specialized cyber-warfare units with the ability to conduct successful offensive cyber operations[20]. Such unchecked military capabilities could have dire consequences for strategic stability at the regional and global levels.

2.3.2. Artificial Intelligence (AI)

Another major technological challenge in the way of successful NRR measures comes from the rapid ingress of AI-driven platforms into the military domain. The utility of AI and ML in the industry can't be questioned, however, the delegation of power to a machine to make battlefield decisions autonomously without human intervention has given rise to several legal and moral questions. The normative discussions on AI cut across various domains such as international law, risks and safety assessment, and technological convergence.

However, the dilemma confronting the world is the application of AI technology in the nuclear realm and the efforts to design an AI-driven nuclear weapons platform[21]. If such a thing happens, it would become extremely impossible to stop the inadvertent or intentional nuclear missile launch. Because of technical limitations and difficulties to

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[17] "Global_zero_commission_on_nuclear_risk_reduction_report_0.Pdf," accessed August 3, 2021, https://www.globalzero.org/wpcontent/uploads/2018/09/global_zero_commission_on_nuclear_risk_reduction_report_0.pdf.

[18] Richard A. Clarke and Robert K. Knake, *Cyber War: The next Threat to National Security and What to Do about It*, 1st ed (New York: Ecco, 2010),p. 10.

[19] Dick Zandee, "Trump's Nuclear Posture Review: A New Rift between Europe and the US?," *Clingendael Policy Brief*, February 2018, 7.

[20] Rafay Baloch, "Cyber Warfare Trends, Tactics and Strategies: Lessons for Pakistan," n.d.

[21] Jessica Cox and Heather Williams, "The Unavoidable Technology: How Artificial Intelligence Can Strengthen Nuclear Stability," *The Washington Quarterly* 44, no. 1 (2021): 69–85.

design and code such an intelligent and autonomous weapon system is near to impossible. Moreover, such a system will highly be susceptible to cyber-attacks and cyber-intrusion. Hence, the reliance on AI-driven nuclear weapons systems or missile defense systems will simply be an act of foolishness[22].

It is necessary to bear in mind the past incidents when technical glitches brought the world near nuclear apocalypse and the presence of a human in the decision-making loop saved the world from nuclear annihilation. In September 1983, a soviet missile alert system gave the false alarm of five incoming US ICBMs. This false alarm was a result of a system glitch; however, it was the presence of a human (Lt. Col. Stanislav Petrov) whose prudence didn't initiate the launch of Soviet nuclear missiles. Another incident that questions the credibility of autonomous systems, happened during the second Iraq war in 2003 when some technical error in the US Patriot Missile Defense System resulted in the shooting down of a US Navy F-18 fighter and a British Tornado[23].

2.3.3. Deep-Fake Technology

The Deep-Fake technology is another AI phenomenon that has added another dimension to the nuclear risks. Deep-Fakes are doctored or fake images, audio or video clips having undistinguishable resemblance with the real person. These fake images, audio, and video clips are generated using the Generative Adversarial Network (GAN) technique, which uses two algorithms i.e., Generator and Discriminator to create a phony image, audio, or video clip. The Deep-Fake technique extracts the voice, facial expressions, and other traits of a person and superimposes them on another. Apart from moral and legal objections associated with this technique, it is extremely dangerous for peace and security. For instance, at the height of a crisis, a phony video or image could have disastrous results especially when the channels of communication are non-existent or ineffective[24]. From the nuclear security perspective, Deep-Fake poses a potential threat to personnel reliability and information security command structure[25].

2.3.4. Quantum Computing

Similarly, the application of quantum computing would also have adverse consequences for nuclear safety and security and will cast adverse impacts on strategic stability. With enormous processing powers, quantum computers will be able to break the nuclear codes easily. If used in combination with cyber and AI-driven weapons as a force multiplier, there is a possibility that they can easily make nuclear deterrence irrelevant[26].

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[22] Elena Sokova, "Disruptive Technologies and Nuclear Weapons," *New Perspectives* 28, no. 3 (September 2020): 292–97, https://doi.org/10.1177/2336825X20934975.

[23] Paul Scharre, *Army of None: Autonomous Weapons and the Future of War* (New York: W.W. Norton & Company, 2019), p. 146,148.

[24] J. M. Porup, "Deepfake Videos: How and Why They Work — and What Is at Risk," CSO Online, March 18, 2021, https://www.csoonline.com/article/3293002/deepfake-videos-how-and-why-they-work.html.

[25] Alexey Averkin et al., "Artificial Intelligence in the Context of Psychological Security: Theoretical and Practical Implications.," in *EUSFLAT Conf.*, 2019.

[26] "NUCLEAR COMMAND-AND-CONTROL IN THE QUANTUM ERA | Nautilus Institute for Security and Sustainability," March 30, 2018, https://nautilus.org/napsnet/nuclear-command-and-control-in-the-quantum-era/.

Despite the fact the cyber technology, AI, and Quantum computing might have enormous benefits in the civilian domain, still, these technologies are not mature enough to be employed in the military domain where the final decision should be made by a human, not a machine[27].

3. An Overview of Nuclear Diplomacy of Pakistan and Efforts to Preserve the Strategic Stability in South Asia

This section traces the history of the nuclearization of South Asia and discusses the broad contours of Pakistan's nuclear diplomacy, it also takes stock of the nuclear and other strategic CBMs between both countries.

3.1. A Brief History of the Nuclearization of South Asia

India and Pakistan are immediate neighbors and got independence from the same colonial power in 1947. However, even after seven decades, they are unable to resolve their outstanding issues peacefully. Since 1947, both countries have fought three full-scale wars in 1948, 1965, and 1971respectively, one limited war in Kargil in 1999 and encountered near to war situations in 1987, 2001, 2002, 2008, and 2019 respectively. A cursory look at all Indo-Pakistan military encounters reveals that except in 1971, Jammu and Kashmir dispute was the root cause behind all conflicts between both countries.

However, the year 1998 was a turning point in the political history of South Asia when both countries ended their covert nuclear programs and emerged as declared nuclear powers. Pakistan's nuclear explosions on 28 and 30 May 1998 were in response to India's nuclear tests. It clears one thing that Pakistan's nuclear test was in response to India and its nuclear program is purely defensive and aimed at protecting the territorial integrity and sovereignty by ensuring credible minimum deterrence[28].Dr, Sannia Abdullah also argues that Indian motivation to get nuclear weapons was driven by global power ambition while Pakistan's nuclear program was aimed at addressing security concerns[29]. Pakistan's first use policy is also meant to deter adversary if it crosses certain thresholds[30].

Pakistan's quest for a nuclear bomb dates back to 1974 when India detonated a nuclear device in Pokhran under the garb of Peaceful Nuclear Explosion (PNE). At that time, the wounds of the 1971 war and the ensuing dismemberment of the country were still fresh. Genuine fears of getting overwhelmed by a militarily superior adversary compelled Pakistan to adopt a nuclear path. Soon after that test, PM Z.A. Bhutto made it clear to build nuclear weapons, even if the people of Pakistan "had to eat grass". However, the journey had never been easy and remained filled with external threats, economic sanctions, and arms embargos[31].

3.2. Theoretical Frameworks to Understand the Nuclearization of South Asia

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[27] Scharre, *Army of None*, p. 252.

[28] Hassan Abbas, *Pakistan's Nuclear Bomb: A Story of Defiance, Deterrence and Deviance* (Haryana, India: Penguin Allen Lane, 2018).p. 293.

[29] Sannia Abdullah, "Pakistan and the Nonproliferation Regime.Final," 2018, https://www.researchgate.net/publication/327742227_Pakistan_and_the_Nonproliferation_Regimefinal.

[30] Dr Sitakanta Mishra, "FEATURED | Pakistan's Nuclear Threshold: Not as Low as Perceived," n.d., 5.

[31] Khan, *Eating Grass: The Making of the Pakistani Bomb, p. 7.*

The theory of realism best explains the nuclearization of South Asia. According to realists and neo-realists, there is a structural flaw in the international governance system. The absence of a central governing authority and the uneven distribution of natural and economic resources have made the world chaotic. In such a scenario, an arms buildup by one country makes another country insecure. Therefore, to protect their sovereignty and territorial integrity, states have limited choices in hand. States balance the power asymmetry by entering into alliances or by transforming themselves into economic and military powers or by accepting the suzerainty of global or regional power[32].

When applied to South Asia to understand the nuclearization of the region, the theory of realism fits well in case of Pakistan. It was the sense of fear of giving up the sovereignty in the hands of a militarily strong adversary like India, it opted for the option of getting nuclear weapons. Similarly, the victory of militarily superior China in 1962, which pushed India to pursue a nuclear path, is presented as a cogent reason behind getting nuclear weapons[33]. However, scholars provide historical evidences that the India's acquiring of nuclear weapons was not security-driven, rather status-driven. According to them it was not Chinese threat, rather quest for global prestige, ambitions to offset adversaries and rivals[34], which nullifies the Indian assertion that it possession of nuclear weapons was purely to counter any Chinese aggression against its sovereignty and territorial integrity.

In the light of the above discussion, it can be concluded that the theory of Realism can be applied to South Asia to have a better understanding of the factors that pushed India and Pakistan to resort to nuclear weapons.

3.3. Nuclear Diplomacy of Pakistan

Broadly defined, Nuclear Diplomacy is the manifestation of a country's foreign policy towards acquiring nuclear technology for both peaceful and military purposes, assuring deterrence and its commitments towards the aspects of nuclear proliferation. Keeping in view Pakistan's history of long-standing disputes with India, and the latter's numerical advantage of conventional forces, Pakistan's nuclear diplomacy has remained successful in achieving the objectives of protecting its national security and territorial integrity via credible minimum deterrence and socio-economic development uses nuclear technology in the civilian sphere. Moreover, Pakistan has always remained committed to the global non-proliferation objectives and always remains ready to resolve all disputes with India through dialogue. The signing of different agreements between both countries to lower the risks of nuclear is also a manifestation of Pakistan's successful nuclear diplomacy[35].

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[32] William A. Galston, "Realism in Political Theory," *European Journal of Political Theory* 9, no. 4 (2010): 385–411.

[33] Jalil Mehdi, "Nuclear Strategy and Regional Stability in Southern Asia," *Journal of Asian Security and International Affairs* 4, no. 1 (April 2017): 123–37, https://doi.org/10.1177/2347797016689229.

[34] Ashfaq Ahmad, Muhammad Ramiz Mohsin, Farzad Ahmed Cheema, "Nehru the Father of Indian Atomic Bomb and Integrated Guided Missile Development Program: A Historical Perspective," *Pakistan Social Sciences Review* 2, no. II (December 31, 2018): 130–42, https://doi.org/10.35484/pssr.2018(2-II)11.

[35] Sher Bano, "Pakistan's Nuclear Diplomacy: Commitment Towards Non-Proliferation," *Modern Diplomacy* (blog), September 14, 2020, https://moderndiplomacy.eu/2020/09/14/pakistans-nuclear-diplomacy-commitment-towards-non-proliferation/.

3.4. Confidence Building Measures (CBMs): A Definitional Understanding

Confidence Building Measures or CBMs are effective diplomatic tools to foster trust among countries and to prevent conflict. According to the Cambridge dictionary, confidence is a feeling of trust in someone or something. The antonyms of confidence are doubt, hesitation, and uncertainty. In diplomacy, CBMs may be defined as a set of unilateral, bilateral, or multilateral measures taken to build confidence and to end tensions between two or more states. CBMs are the diplomatic initiatives that help to repair relations between countries, marred with distrust, resultantly reduce the chances of a conflict. CBMs create a conducive environment for the states to build trust for negotiating a treaty or agreement to end the conflict. CBMs are backed by information exchanges, pre-notifications, and verification to measure the sincerity and commitment of all the parties concerned[36].

3.5. An Appraisal of Pakistan's Efforts for Nuclear-Weapons Free South Asia

Since 1974, Pakistan's made several efforts and floated numerous proposals to keep South Asia free of nuclear weapons, however, India turned down all the proposals on the contention that until and unless China doesn't give up nuclear weapons, such initiatives will be of no value. Another reason behind the failure of the proposal was the Indian hegemonic designs and the ambitions to become a global power. The main purpose of nuclear CBMs offered by Pakistan to India was to protect the strategic stability in South Asia and conflict resolution via peaceful means.

The fowling table depicts the chronology of different proposals given by Pakistan to Indian to keep South Asia free of nuclear weapons[37].

Year	Proposal
1974	South Asian Nuclear Weapons Free Zone Agreement
1978	Joint Renunciation of Acquisition or Manufacture of Nuclear Weapons
1979	Mutual Inspection of Nuclear Facilities
1979	Simultaneous Acceptance of IAEA Full Scope Safeguards
1979	Simultaneous Accession to the NPT
1987	Bilateral Nuclear Test Ban Treaty
1994	South Asia Zero Missile Zone
1998	Soon after becoming a declared nuclear power, Pakistan offered India to establish a Strategic Restraint Regime (SRR) in South Asia. The main points of the proposal were: i) Rationalizing the number of nuclear forces. ii) Rationalizing the number of conventional forces. iii) Not to deploy any ballistic missile defense system.
1998	Simultaneous adherence to Comprehensive Test Ban Treaty (CTBT)
2016	Bilateral Moratorium on Nuclear Testing

[36] Johan J⊘rgen Holst, "Confidence-building Measures a Conceptual Framework," *Survival* 25, no. 1 (January 1, 1983): 2–15, https://doi.org/10.1080/00396338308442072.
[37] Naeem Ahmad Salik, "CONFIDENCE BUILDING MEASURES BETWEEN INDIA AND PAKISTAN," 2010, 38.

3.6. An Overview of Nuclear CBMs between India and Pakistan

The following list takes stock of Nuclear CBMs between India and Pakistan[38].

a) Agreement on the Prohibition on Attacking Nuclear Sites and Facilities (1988)

On December 31, 1988, both countries concluded an agreement that prohibits attacking civilian nuclear sites. The agreement came into force on January 27, 1991. Under the same agreement, every year in January both countries share the list of their civilian nuclear sites along with geographical coordinates. Since 1992, both countries are exchanging the lists regularly[39].

b) Foreign Secretaries Nuclear Hotline (2004)

In 2004, a nuclear hotline was established between the Foreign Secretaries of both countries. Its purpose was to avert any misunderstanding which might lead to nuclear war[40].

***c)* Agreement on Pre-Notification of Flight Testing of Ballistic Missiles (2005)**

On October 3, 2005, both countries signed the agreement on pre-notification of flight testing of ballistic missiles. According to the agreement, both countries are bound to inform 72 hours before the flight test of land or sea-launched surface to surface ballistic missiles. As per the agreement, both countries ensure that the test site and the planned impact area are not falling within 40 Kms and 75 Kms of the international boundary or the LoC. Moreover, the planned trajectory of the ballistic missiles can't be directed towards the international border or the LoC. However, this agreement covers only ballistic missiles, not cruise missiles[41].

d) Agreement on Reducing the Risk from Accidents Relating to Nuclear Weapons (2007)

In February 2007, both countries signed the Agreement on Reducing the Risk from Accidents Relating to Nuclear Weapons which was renewed for five years in 2012 and 2017 respectively. According to the agreement both countries notify each other immediately in the event of an accident relating to a nuclear weapon with risk of radioactive fallout[42].

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[38] Adil Sultan, *Universalizing Nuclear Nonproliferation Norms: A Regional Framework for the South Asian Nuclear Weapon States*, 1st ed. 2019 (Cham: Springer International Publishing : Imprint: Palgrave Pivot, 2019), https://doi.org/10.1007/978-3-030-01334-9.

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[41] "AGREEMENT-BETWEEN-INDIA-AND-PAKISTAN-ON-PRE-NOTIFICATION-OF-FLIGHT-TESTING-OF-BALLISTIC-MISSILES-2005.Pdf," accessed August 7, 2021, https://cpakgulf.org/wp-content/uploads/2016/04/AGREEMENT-BETWEEN-INDIA-AND-PAKISTAN-ON-PRE-NOTIFICATION-OF-FLIGHT-TESTING-OF-BALLISTIC-MISSILES-2005.pdf.

[42] "PA07B0425.Pdf," accessed August 7, 2021, https://mea.gov.in/Portal/LegalTreatiesDoc/PA07B0425.pdf.

3.7. Other Conventional CBMs between India and Pakistan

Following is the list of other significant strategic CBMs between India and Pakistan[43].

a) Hot Lines

To eliminate doubts and to defuse tensions, over time India and Pakistan established the following channels of communication at political and military levels

DGMOs Hotline: This military level hotline between the DGMOs of both countries was first established in 1971. This hotline has remained instrumental for reducing tensions between both countries on the Line of Control (LoC).

Maritime Hotline: In January 2004, a hotline was established between Pakistan Maritime Security Agency (PMSA) and the Indian Coast Guards. Both countries use this channel of communication for the exchange of information on maritime affairs, especially relating to fishermen who frequently cross into each other's maritime boundaries[44].

b) Agreement on Advance Notification on Military Exercises, Maneuvers and Troops Movement (1991)

On April 6, 1991, both countries signed *Agreement on Advance Notification on Military Exercises, Maneuvers, and Troops Movements.* According to this agreement, it is obligatory for both countries to timely inform each other before conducting military exercises and troop's movement. This agreement helps to avert misinterpretation of any large-scale movement of troops and no to perceive it as preparation for war[45].

c) Agreement on the Prohibition of Chemical Weapons (1992)

In August 1992, both countries signed an agreement prohibiting the development, stockpiling, and use of chemical weapons. Under the same agreement, both countries signed the Chemical Weapons Convention (CWC) in January 1993[46].

d) Prevention of the Violation of Airspace (1991)

In April 1991, both countries signed an Agreement on the Prevention of the Violation of Airspace, prohibiting the flying of combat aircraft including fighter jets, reconnaissance aircraft, military trainers, and armed helicopters within 10 km of each other's airspace. This also includes the prohibition of flying over the territorial waters of both countries[47].

[43] Maria Saifuddin Effendi and Dr Ishtiaq Ahmad, "India–Pakistan CBMs since 1947 A Critical Analysis," *South Asian Studies* 31, no. 1 (2020).
[44] "Pakistan Hotline Prevents Fishermen Crossing," *Reuters*, January 31, 2007, sec. Internet News, https://www.reuters.com/article/oukin-uk-india-pakistan-fishermen-idUKDEL2937820070131.
[45] "CBMHandbook3-1998-i-Pagree.Pdf," accessed August 7, 2021, https://www.stimson.org/wp-content/files/CBMHandbook3-1998-i-pagree.pdf.
[46] "India-Pakistan Agreement on Chemical Weapons | Treaties & Regimes | NTI," accessed August 7, 2021, https://www.nti.org/learn/treaties-and-regimes/india-pakistan-agreement-on-chemical-weapons/.
[47] "Agreement Between Pakistan and India on Prevention of Air Space Violation • Stimson Center," *Stimson Center* (blog), May 5, 2011, https://www.stimson.org/2011/agreement-between-pakistan-and-india-on-prevention-of-air-space-violat/.

e) **India-Pakistan Expert's Level Dialogue on Conventional and Nuclear CBMs (2004)**

The process started in 2004 and remained lasted till 2012. The last round of the dialogue was held in New Delhi in December 2012. In 2014, India refused to hold further dialogues decrying the lack of conducive environment trust among both countries. Since then, the process is confronting a stalemate[48].

4. How Emerging Technologies are Threatening for the Strategic Stability of South Asia

Emerging technologies are changing the dynamics of warfare in South Asia, resultantly threatening the strategic stability of the region. The introduction of hypersonic delivery vehicles, anti-ballistic missile defense systems, and ASAT missile tests and growing incidents of cyber-attacks on critical infrastructure may worsen the security situation in South Asia. In this regard, the unbridled inclination of super-powers towards India, raising its Indian status to "*Net-Security Provider*" and signing of defense pacts like GSOMIA, COMCASA, LEMOA, BECA, might have a detrimental impact on crisis stability, arms control stability, and deterrence stability in South Asia[49].

If analyzed, the nuclear CBMs between India and Pakistan only address the traditional threats to the NRR and don't cater to the threats emanating from the emerging technologies. This is because these CBMs were concluded when the role of emerging technologies in the military sphere was limited in South Asia. Moreover, the absence of frequent dialogues due to strained relations didn't allow both countries to discuss the issue of emerging technologies.

Considering the technological development and the extent of application of emerging technologies in the military sphere in South Asia, out of the10 disruptive technologies mentioned in Kings College London's report[50], the following five technologies have the potential to exacerbate the risks associated with the inadvertent or intentional use of nuclear weapons in the region:

a) Cyber Operations
b) Deepfake Technology
c) Hypersonic Missiles
d) Kinetic Anti-Satellite (ASAT) Capabilities
e) Swarm Drones and AI-Driven Weapons

4.1. Cyber Operations

Cyberspace in South Asia is getting militarized gradually. Indian Army's Land Warfare Doctrine of 2018 (LWD-18) also discusses developing cyber warfare and

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[48] KS Manjunath, Seema Sridhar, and Beryl Anand, "Indo-Pak Composite Dialogue 2004-05: A Profile," 2006, 14.
[49] Samran Ali, "Indo-US Foundational Agreements: Contributing to India's Military Capabilities," n.d., 6.
[50] Favaro, "Weapons of Mass Distortion: A New Approach to Emerging Technologies, Risk Reduction, and the Global Nuclear Order."

information warfare capabilities[51]. The recent statement of Pakistan's National Security Advisor is extremely perturbing in which he has accused India of conducting coordinated cyber-attacks on Pakistan's information infrastructure. It was for the first time that a high-ranking government official of Pakistan blamed India for cyber-attacks[52]. Another disturbing aspect of these cyber-attacks is that the hackers are now targeting the critical infrastructure in South Asia. September 2019 attack on KudanKulam nuclear power plant in India was the first cyber-attack on a nuclear installation in South Asia. There were reports that the same malware also targeted the Indian Space and Research Organization (ISRO)[53]. In September 2020, K-Electric, a major electricity supply company in Karachi came under ransomware (code-named *Netwalker*) which rendered its online customer support system ineffective. The Involvement of non-state actors is extremely dangerous especially when attribution remains the most challenging aspect of cyber-attacks[54].

Cyberspace in South Asia has also become a platform for spreading fake news, propaganda, and launching disinformation campaigns, EU *DisinfoLab* report is a case study example of such targeted online campaigns launched by India against Pakistan[55]. Another worrying aspect is the online dissemination of sensitive information like flight routes and uploading imagery of sensitive military installations, missile sites obtained through IMINT (Imagery Intelligence) and OSINT (Open-Source Intelligence). Leaking such sensitive information in the public domain may endanger the security of such strategic locations[56].

4.2. **Deep-Fake Technology**

Deep-Fake is an upsetting innovation of AI which employs the GAN technique of deep learning. In this technology, AI algorithms create a fake image, audio, or video clip having an unidentifiable resemblance with a real person[57]. Apart from the ethical and moral dilemma attached to this technology, it could become a major reason behind political turmoil and instability especially in a situation like Balakot Crisis in 2019. In such charged environment, a fake video impersonating the Indian Prime Minister declaring war on Pakistan may have catastrophic consequences. A similar incident also happened in the past, in 2008 soon after Mumbai Attacks, a hoax call was made to the then President of Pakistan, Asif Ali Zardari, impersonating Indian Foreign Minister Pranab Mukherjee

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51 Vivek Chadha, "Land Warfare in the Indian Context: Time for a Transformative Shift?," n.d., 17.

52 "Mastermind of Johar Town Blast Is an Indian Citizen Associated with RAW: NSA Moeed Yusuf - Pakistan - DAWN.COM," accessed August 3, 2021, https://www.dawn.com/news/1633170.

53 "ISRO Was Targeted by the Same Malware That Was Used to Attack NPCIL's Kudankulam Nuclear Plant: Report- Technology News, Firstpost," accessed August 3, 2021, https://www.firstpost.com/tech/india/isro-was-targeted-by-the-same-malware-that-was-used-to-attack-npcils-kudankulam-nuclear-plant-report-7608621.html.

54 "K-Electric Struck by 'Ransomware' - Newspaper - DAWN.COM," accessed August 3, 2021, https://www.dawn.com/news/1578882.

55 "Indian Chronicles: Deep Dive into a 15-Year Operation Targeting the EU and UN to Serve Indian Interests," *EU DisinfoLab* (blog), accessed August 3, 2021, https://www.disinfo.eu/publications/indian-chronicles-deep-dive-into-a-15-year-operation-targeting-the-eu-and-un-to-serve-indian-interests/.

56 Zaki Khalid, "Adverse Impact of IMINT and OSINT on Pak-India Cyber CBMs," *Centre for Strategic and Contemporary Research* (blog), May 19, 2020, https://cscr.pk/explore/themes/defense-security/adverse-impact-of-imint-and-osint-on-pak-india-cyber-cbms/.

57 "Artificial Intelligence, Autonomy, and the Risk of Catalytic Nuclear War," Modern War Institute, March 18, 2021, https://mwi.usma.edu/artificial-intelligence-autonomy-and-the-risk-of-catalytic-nuclear-war/.

threatening to attack Pakistan. This phone call put nuclear-armed Pakistan on red alert. The hoax call was allegedly made by Ahmed Omer Saeed Sheikh, an Al-Qaeda militant who was detained in Hyderabad jail at that time. This near-war scenario developed because of the lack of trust and the ineffectiveness of existing channels of communication between both countries[58].

4.3. Hypersonic Missiles

India's successful testing of Hypersonic Technology Demonstrator Vehicle (HSTDV) in September 2020, was another disturbing development that could have long-lasting impacts on the strategic stability of the region. Hypersonic missiles can travel through the atmosphere at Mach 5 (5 times faster than the speed of sound), and can easily dodge the enemy's ballistic missile defense systems. Hypersonic missiles can hit the targets deep inside the enemy territory without getting detected. A hypersonic cruise missile, traveling at Mach 7 can reach from New Delhi to Lahore in 2.94 minutes. India was in pursuit of developing hypersonic weapons because of several reasons. Firstly, possessing such sophisticated technology will help India to become part of the superpower's club. Secondly, India may use them to launch counterforce disarming strikes against Pakistan to eliminate its nuclear arsenal[59].

4.4. Kinetic Anti-Satellite (ASAT) Capabilities

India's superpower aspirations touched new heights when it conducted an anti-satellite (ASAT) missile test in March 2019, making it the fourth country after the US, Russia, and China to have this capability. According to NASA, the Indian ASAT missile test created a large number of orbital debris which could damage the International Space Station and other satellites[60]. During the test, India targeted its satellite orbiting in the Low Earth Orbit (LEO), 274 km above the earth. According to experts, this test will further accelerate Indian efforts to develop an advanced Ballistic Missile Defence (BMD) System. Current Indian BMD systems can intercept short-range missiles, however, ASAT missile testing will enable India to intercept and destroy medium-range and long-range ballistic missiles. In such a situation, the presence of advanced satellite launch vehicles (SLV) such as GSLV Mark III with the capacity to carry a payload of 8000 kg into earth's orbit, makes the situation more precarious[61].

According to experts, such attempts are aimed at weakening Pakistan's nuclear deterrence[62]. Pakistan has always remained against all such activities which lead towards the militarization of outer space and supports the legally binding instruments to promote norms and responsible behavior in outer space such as PAROS (Prevention of Arms Race

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[58] "Jailed Militant`s Hoax Calls Drove India, Pakistan to Brink of War," DAWN.COM, November 26, 2009, http://beta.dawn.com/news/852798/jailed-militant-s-hoax-calls-drove-india-pakistan-to-brink-of-war.

[59] Dr. Adil Sultan and Itfa Khursheed, "Hypersonic Weapons in South Asia: Implications for Strategic Stability," *IPRI Journal* 21, no. 01 (June 30, 2021): 61–81, https://doi.org/10.31945/iprij.210103.

[60] "India's Anti-Satellite Test Created Dangerous Debris, NASA Chief Says | Space," accessed July 12, 2021, https://www.space.com/nasa-chief-condemns-india-anti-satellite-test.html.

[61] "GSLV Mk III - ISRO," accessed August 8, 2021, https://www.isro.gov.in/launchers/gslv-mk-iii.

[62] Atul Aneja, "Anti-Satellite Test Can Steel India's Ballistic Missile Defences: Chinese Blog," *The Hindu*, April 11, 2019, sec. International, https://www.thehindu.com/news/international/anti-satellite-test-can-steel-indias-ballistic-missiledefences-chinese-blog/article26803333.ece.

in Outer Space) in CD, to prevent outer space from becoming another arena of military conflict[63].

4.5. Swarm Drones and AI-Driven Weapons

Artificial Intelligence (AI) is rapidly changing the traditional methods of warfighting. The recent war between Armenia and Azerbaijan is an example of this fact that how Israeli Harop loitering munition, also known as the "kamikaze" drones played a key role in Azerbaijan's victory[64]. India is also on the way to equip its military with AI-driven weapons and gadgets and also demonstrated them during the Annual Army Day parade in January 2021, during which a swarm of 75 drones took parts and displayed their ability to strike their targets with high precision. It was for the first time that India made public its AI-driven arsenal[65]. This development should be analyzed in conjunction with the 2019's aerial skirmish between Pakistan and India which cost India its Mig-21 Bison and the capturing of a fighter pilot. Swarm drones if inducted, will further embolden India to conduct a cross-border strike inside Pakistan without the fear of losing its pilot or a costly fighter aircraft and to avert the ensuing embarrassment.

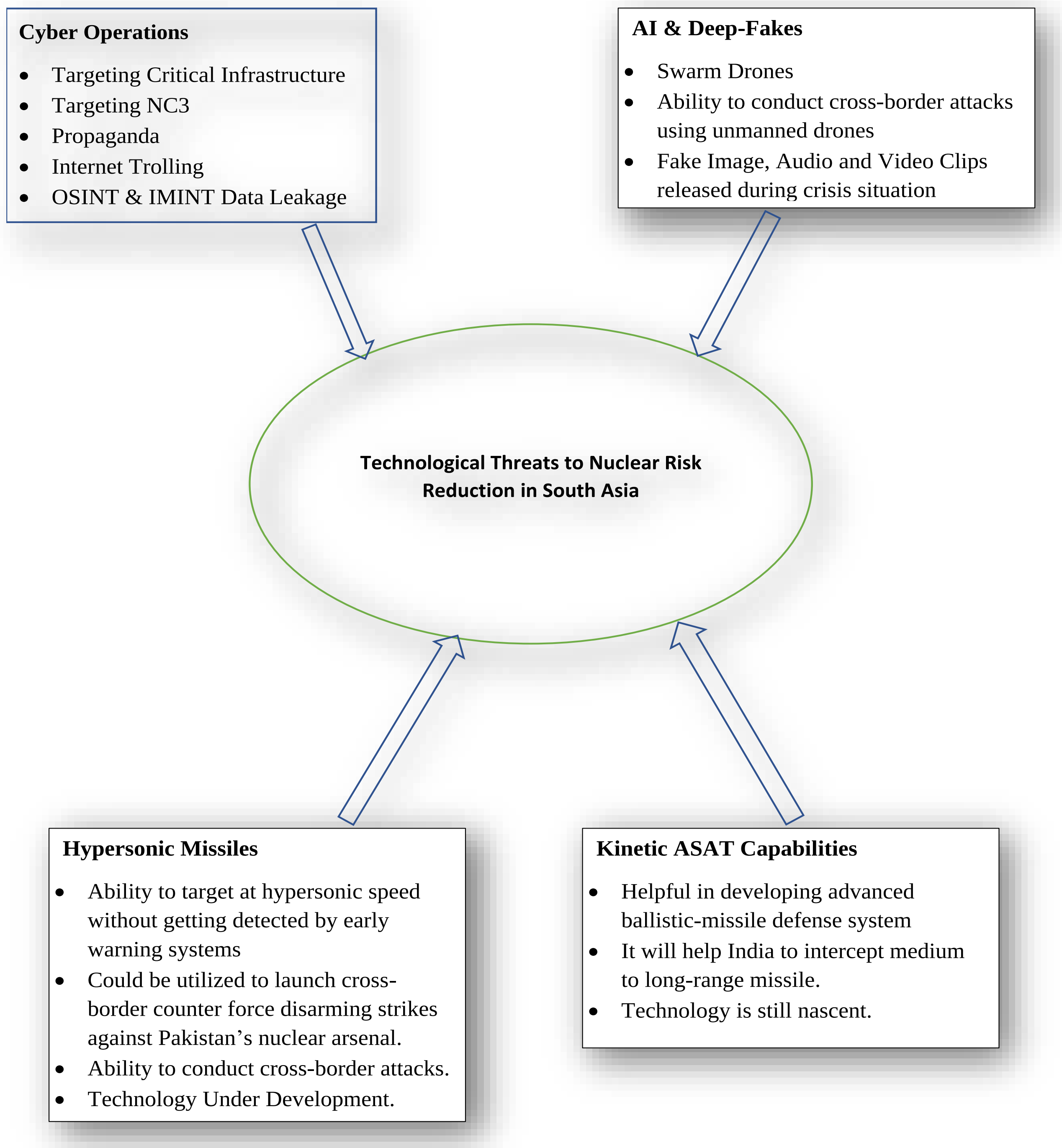
4.6. Graphical Depiction of Emerging Technology Threats in South Asia

The following diagram depicts the threats associated with emerging technologies discussed above in a graphical manner.

[63] "Arms Control & Disarmament - Pakistan Mission to the UN, Geneva," accessed August 7, 2021, https://www.pakungeneva.pk/TopicsPage.aspx?TopicID=1.

[64] "War in the Caucasus: Lessons," *The Friday Times* (blog), November 19, 2020, https://www.thefridaytimes.com/war-in-the-caucasus-lessons/.

[65] "From Surveillance to Combat: Decoding India's Drone Mission - India News," accessed August 3, 2021, https://www.indiatoday.in/india/story/decoding-india-drone-mission-surveillance-combat-jammu-attack-1820965-2021-06-30.



5. Regulating the Military Use of Emerging Technologies in South Asia: A Way Forward

5.1. CBMs and Disputes Resolution

India and Pakistan have taken several CBMs to reduce tensions, but the result is quite disheartening. Michael Krepon best explains the reason behind the failure of CBMs between both countries. According to him, CBMs between India and Pakistan are not "*confidence-building*" rather "*competition-building*" measures and not meant for reducing tensions rather gaining political mileage. That is why CBMs have largely been bypassed or remained dormant during times of crisis[66]. Therefore, there is a need to focus on real drivers of conflicts in South Asia instead of solely relying on CBMs which can't be a substitute for dispute resolution. In this regard, Pakistan and India should start discussing Strategic Restrain Regime (SRR), the proposal offered by Pakistan to India in 1998. The main points of the proposal were: i) rationalize the number of nuclear forces. ii) rationalizing the number of conventional forces. iii) not to deploy a ballistic missile defense system. It's a low hanging fruit, and could pave the way for the long-lasting stability in the region[67].

5.2. Nuclear Risk Reduction Centers (NRRCs)

The establishment of NRRCs will be an innovative step in South Asia. In 1987, the US and USSR signed the U.S.-Soviet Agreement on the Establishment of Nuclear Risk Reduction Centers (Amended in 2013), to prevent the crisis from arising by reducing the risk of miscommunications, and misunderstandings. Under this agreement, NRRCs were established in Moscow and Washington and were connected via secure and reliable communication links to enable the fast and timely exchange of critical information and data (both in text and graphical formats). The NRRCs didn't replace rather supplemented the existing channels of strategic communications and hotlines. These NRRCs, which operate round the clock 365 days a year, exchange notifications relating to nuclear and conventional arms control, chemical weapons destruction, ballistic missile launch notifications, and cyber incidents[68].

Considering the lack of trust between India and Pakistan and their tendency to go up swiftly on the escalation ladder, the formation of NRRCs is indispensable. The need for these centers should be analyzed in the context of 2019's Balakot crisis when instead of utilizing the Foreign Secretaries hotlines, India preferred media and publicly delivered political statements for messaging. South Asia can't afford such Indian brinkmanship and bypassing of existing channels of communication in crises.

India and Pakistan may explore the possibility of establishing NRRCs in Islamabad and New Delhi connected reliable and encrypted communication links, which will create an additional and permanent line of communication and remain functional round the clock 365 days a year. These NRRCs will work similarly to NRRCs in the US and Russia. Diplomats and technical experts from both sides may be staffed to look after the operations of the centers. These NRRCs will exchange information relating to missiles flight test notification, cyber-incidents, information about nuclear accidents, troops' movement for exercise and air space violations, etc. These centers will be effective to counteract a situation having the potency to ignite a war between both nuclear-armed neighbors.

[66] Rafi uz Zaman Khan, "Nuclear Risk-Reduction Centers," in *Nuclear Risk Reduction in South Asia*, ed. Michael Krepon (New York: Palgrave Macmillan US, 2004), 171–81, https://doi.org/10.1057/9781403981684_9.

[67] "Pakistan's Official Position on SRR," accessed February 4, 2022, https://mofa.gov.pk/acdis/.

[68] "Risky Business: Four Ways to Ease U.S.-Russian Nuclear Tension | Arms Control Association," accessed August 3, 2021, https://www.armscontrol.org/act/2019-09/features/risky-business-four-ways-ease-us-russian-nuclear-tension.

Moreover, NRRCs will also be helpful to portray a positive image of both countries as responsible nuclear powers committed to deal with nuclear risks[69].

5.3. Establishing Cybersecurity Ecosystem in Pakistan

An effective and resilient cybersecurity ecosystem is indispensable for deterring cyber threats. Pakistan's weak cyber threat management and response system are not capable to effectively deter threats emanating from cyberspace. The recent revelations of Project Pegasus[70] and the exposés of the Sophos Labs report published in January 2021[71] are extremely alarming and expose the fragility of cybersecurity infrastructure in the country. Pakistan is facing a multitude of cybersecurity challenges in cyberspace. Rising cyber-attacks against the government and private websites, fake news, targeted disinformation campaigns, phishing attacks, Distributed Denial of Service (DDoS) attacks are some facets of cybersecurity challenges confronted by the State[72]. If compared with other regional countries, Pakistan's cybersecurity apparatus is one of the weakest in the region. The 2020 Global Cybersecurity Index (GCI) of ITU (International Telecommunication Union), which measures the effectiveness of the cybersecurity infrastructure of a country, ranks Pakistan at 79 out of 193 Member States. The same index places India at 10th, Bangladesh at 53rd, and Iran at 54th position respectively. It means that in comparison to regional countries, the cybersecurity infrastructure of Pakistan is not strong enough to counter cyber threats[73].

Pakistan is in process of upgrading its cybersecurity ecosystem. The approval of the National Cybersecurity Policy by the federal cabinet is a step in the right direction. This policy includes almost all the ingredients necessary to build up a resilient cybersecurity infrastructure in Pakistan. It envisions establishing an institutional framework for cybersecurity in the country such as the creation of CERTs (Computer Emergency Response Teams), and nSOC (National Security Operation Center) to protect critical infrastructure, working on information security standards for the public and private sector, capacity building, R&D, foreign collaborations, etc. The policy will be instrumental in hardening the security and better surveillance of Pakistan's cyberspace[74].

5.4. Global Emerging Technology Regulations: As an Indispensable Component of Pakistan's Foreign Policy

Considering the growing risks of entanglement between nuclear and conventional weapons because of emerging technologies, Pakistan must keep on sensitizing the world for the need for an open dialogue on norms building and CBMs for the military use of

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[69] Chris Gagné, "Nuclear Risk Reduction in South Asia: Building on Common Ground," in *Nuclear Risk Reduction in South Asia*, ed. Michael Krepon (New York: Palgrave Macmillan US, 2004), 43–65, https://doi.org/10.1057/9781403981684_4.

[70] "Pegasus Snooping: Pakistan Probes Whether PM Khan's Phone Hacked," accessed August 3, 2021, https://www.aljazeera.com/news/2021/7/20/pegasus-snooping-pakistan-imran-khan-phone-hacked.

[71] "New Android Spyware Targets Users in Pakistan," *Sophos News* (blog), January 12, 2021, https://news.sophos.com/en-us/2021/01/12/new-android-spyware-targets-users-in-pakistan/.

[72] Muhammad Riaz Shad, "Cyber Threat Landscape and Readiness Challenge of Pakistan," n.d., 19.

[73] "Global Cybersecurity Index 2020," n.d., 172.

[74] "Cabinet Approves National Cyber Security Policy," The Express Tribune, July 27, 2021, http://tribune.com.pk/story/2312448/cabinet-approves-national-cyber-security-policy.

emerging and frontier technologies. Pakistan has always remained supportive of the idea of norms building and legally binding instruments to regulate the military use of such technologies and to stop the further weaponization of outer space, and is one of few countries which support banning lethally autonomous weapons systems (LAWS)[75]. In addition to this, Pakistan must guarantee its presence on multilateral forums such as UN OEWG (Open-Ended Working Group) and GGE (Group of Governmental Experts) on developments in the field of information and telecommunications in the Context of International Security, UN GGE on emerging technologies in areas of LAWS, Conference on Disarmament (CD) and SCO, etc. Pakistan may initiate bilateral dialogues on cybersecurity and emerging technologies with China, Russia, Turkey, and other countries for technical cooperation and formulate a joint strategy to push for the legally binding instrument to regulate the military use of emerging technologies.

5.5. Consolidating Existing Channels of Communication

Hotlines and other channels of communication between civilian and military leadership are essential for trust-building and to mitigate the risks associated with the inadvertent or intentional use of nuclear weapons. India and Pakistan have such hotlines at DGMOs and Foreign Secretaries levels but remain ineffective during the crisis. The same thing happened during 2019's Balakot Crisis when instead of utilizing these communication lines, India preferred messaging through media and publicly delivered political statements. Effective utilization of these hotlines has become more indispensable in the context of challenges posing by deep-fake and other emerging technologies. There is a need to further consolidate the existing hotlines mechanism between India and Pakistan and to explore the other modern modes of fast and reliable exchange of critical information such as NRRCs, to avoid confusion and miscalculation.

5.6. Cyber CBMs Between India and Pakistan

As discussed above that the growing incidents of cyber-attacks on critical infrastructure in South Asia could be detrimental for the strategic instability and calls for the need for Cyber CBMs between both countries. Knowing the fact that cyber-attacks lack the element of attribution and an incident similar to 2019's cyber-attack on the Kudankulam nuclear power plant in India or anywhere in South Asia may bring both countries close to war. Tughral Yamin has envisaged a list of CBMs which can be instrumental in fostering trust between the nuclear-armed neighbors in cyberspace[76]:

Agreement to Refrain from Cyber Targeting of Civilian Nuclear Installations: This agreement stops both countries from attacking the civilian nuclear sites. Article 1 of the 1988's Agreement on the Prohibition of Attack against Nuclear Installation and Facilities between India and Pakistan could be modified by making an explicit reference to cyber-attacks.

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[75] "Stopping Killer Robots," Human Rights Watch, August 10, 2020, https://www.hrw.org/report/2020/08/10/stopping-killer-robots/country-positions-banning-fully-autonomous-weapons-and.

[76] Tughral Yamin, "Developing Information-Space Confidence Building Measures (CBMs) between India and Pakistan," June 1, 2014, https://doi.org/10.2172/1200674.

Agreement to Refrain from Cyber Targeting of Critical Infrastructure: An agreement similar to the 1988's Agreement on the Prohibition of Attack against Nuclear Installation and Facilities may be signed which will prohibit the targeting of critical infrastructure (Financial Systems, Banking Sector, Electric Grids, Water Supply Systems, Civilian Aviation System, Health System) by cyber means.

Cyber Hotlines: A cyber hotline similar to the one which exists between Russia and the USA[77] may be established which will link together concerned authorities in both countries to exchange critical information in case of a cyber-attack especially when the identity of the attacker is unknown.

Agreement to Refrain from Online Propaganda: Both countries may agree to not using cyberspace for propaganda against each other. In this regard, the Liaquat-Nehru Pact of 1950 could serve as a template for such an agreement[78]. In this pact, both countries expressed their commitment to take effective measures against the dissemination of mischievous news or opinion which may provoke communal hatred and not permit propaganda which could be detrimental to the territorial integrity and may incite war between both countries. An agreement with the same provision that applies to cyberspace may be signed by India and Pakistan.

Pakistan-India Cyber Agreement: Both countries may agree similar to the US-China Cyber Agreement signed in 2015, which prohibits cyber theft of intellectual property and commercial secrets, cooperation and exchanging information to hunt down cyber criminals, promoting norms for responsible state behavior in cyberspace, and establishing a bilateral high-level cyber dialogue on cybercrimes and related issues[79].

Regional CERTs: Computer Emergency Response Teams (CERTs) under the auspices of SCO and SAARC may be established. Such a regional approach will help to counter cybercrimes and trust-building among the member countries.

6. Conclusion

The efficacy of emerging technologies and their role in socio-economic development is undeniable. Indeed, they have brought ease and comfort in human life and are essential for the modernization of society. However, their unregulated use in the military domain is creating a lot of challenges for peace and security especially when they are utilized to render nuclear deterrence ineffective. Such a scenario threatens strategic stability and further exacerbates the risks associated with the inadvertent or intentional use of nuclear weapons.

South Asia is also confronting a similar situation where India is in pursuit to use hypersonic missile technology to launch preemptive counterforce strikes against Pakistan's nuclear arsenal. Growing cyber-attacks on critical infrastructure like nuclear power plants

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[77] Sean Gallagher, "US, Russia to Install 'Cyber-Hotline' to Prevent Accidental Cyberwar," Ars Technica, June 18, 2013, https://arstechnica.com/information-technology/2013/06/us-russia-to-install-cyber-hotline-to-prevent-accidental-cyberwar/.

[78] "Nehru-Liaquat Agreement, 1950," n.d., https://mea.gov.in/Portal/LegalTreatiesDoc/PA50B1228.pdf.

[79] Scott W. Harold, "The U.S.-China Cyber Agreement: A Good First Step," August 1, 2016, https://www.rand.org/blog/2016/08/the-us-china-cyber-agreement-a-good-first-step.html.

are further aggravating the risks of escalation. Deep-Fake technology has added another dimension to the nuclear risks in South Asia. Therefore, a region that is home to three nuclear-armed neighbors has a political history marred with conflicts and lack of trust, where channels of strategic communications are never properly utilized, confusion, and miscalculation caused due to emerging technologies may end up in a disaster. All such situation calls for dialogue and CBMs supplemented by sincerer efforts to resolve all outstanding disputes.

As discussed above, challenges posed by disruptive emerging technologies are not restricted to South Asia only, it's a global challenge and needs global efforts. In this regard, Pakistan has always remained supportive of the legally binding instruments to promote responsible behaviors and to regulate the use of emerging technologies in the military sphere. Pakistan is also raising its voice against the rapid weaponization of outer space and stresses the need for a legally binding instrument like PAROS (Prevention of Arms Race in Outer Space). Since 1974, Pakistan has offered several proposals to keep South Asia free of nuclear weapons but met with Indian refusal. Both countries may take several steps such as the formation of NRRCs, Cyber CBMs, effective utilization of hotlines and other channels of communication, and signing an agreement that prohibits the cyber targeting of critical infrastructure. All these measures will be instrumental to mitigate the nuclear risks and threats associated with the unregulated military use of emerging technologies.

Advances in the Field & Societal Benefits

Human Gut Microbiome and Impact on Health Security

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Background

Human beings are supraorganisms as they possess a mixture of human and non-human cells, as elucidated by the ground-breaking study of the Human Microbiome Project. The reason behind studying this concept was to understand the human microbiome and underlying facts concerning its role in maintaining overall human health. As humans are supraorganisms, their genetic landscape is a summation of their own genome and microbial genome, along with the co-emergence of both with the passage of time. Hence, for clear understanding of the human genome and its physiological traits; we need to study the microbial diversity of human and factors that involve in the distribution and evolution of their microbiota. The findings are expected to enrich our understanding and give us a new dimension to study the basis behind human evolution that how change in lifestyle and biosphere impact the overall health of humans due to change in microbial diversity (Gill *et al.,* 2006; Turnbaugh *et al.,* 2007).

Although microbiota and microbiome are two terms used interchangeably, they are slightly different. The microbiota means microorganisms existing in a particular environment. This is studied with the help of the molecular techniques, mainly 16S rRNA analysis, which helps us to explore the microbial taxa present in different environmental samples (Cho and Blaser, 2012; Ursell *et al.,* 2012). On the contrary, microbiome means "the habitat as a whole, thus incorporating the biotic and abiotic factors, encompassing host and microorganism genomes and environmental conditions" (Cho and Blaser, 2012; Whiteside *et al.,* 2015). Therefore, it is a broader term that further enriches our knowledge regarding microbial world (and their role in our body) and how this can support the sustainability in terms of keeping good health that directly links with Sustainable Development Goal No. 3 - "Ensure healthy lives and promote well-being for all at all ages".

Microbiome: a hidden organ explored through latest technologies

The microbiome of humans works as a hidden organ that includes bacteria, archaea, fungi and viruses. They are called hidden organs because of their role in maintaining health by strengthening our immune system and helping with digestion as well along with some other functions (Ley *et al.*, 2008). Among these microorganisms, bacteria have been the most widely studied so far. The agents of the hidden organ are present in different locations in the body like inside and on the surface of the gut. The number of these microbes are $10^{12} - 10^{14}$ which is 10 times of humans own cells. Their genome consists of 3.30 million numbers of genes which is 150 times greater than our own genes. There are about 1000 bacterial species that have been explored in the gut of humans (Ley *et al.*, 2006a; Qin *et al.*, 2010**).** This extended genome presents multigenomic symbiosis that works for both, translational and metabolic level (Dethlefsen *et al.,* 2007). Owing to these bacteria we retain certain traits that we might not have on our own otherwise. In addition to this, microbial niche plays an important role in extracting nutrients from the food we consume (Turnbaugh *et al.*, 2006).

Advances in the field of bioinformatics have enabled a better understanding of the role of microbiome through mapping of non-human DNA as well as their phylogenetic relationship. These techniques give more detailed and authentic taxonomic classification and recognition of both cultured and uncultured clones (Clarridge, 2004). High throughput technique are used for sequencing DNA in order to explore microbial niches in different communities that are present in diverse environments, e.g., in the skin, saliva, intestine and colon. The majorly studies have been conducted on humans GI tract (Hildebrandt *et al.,* 2009; Turnbaugh *et al.,* 2010). High throughput sequencing strategies such as pyrosequencing and Illumina MiSeq gives deep insights to the microbial profile of a subject sample, but also help us in understanding the ecological relationship between them. These developments allow us to identify organisms and their relative abundance, along with the function of these microbes that they perform while living in a particular environment (given sample) (Handelsman *et al.,* 1998; Langenheder *et al.,* 2010). These technologies enhance our knowledge regarding microbial world, even though a lot of challenges and sources of error can occur, nonetheless numerous modifications are made to overcome such issues and interpret results accurately (Tyler *et al.,* 2014).

Bioinformatics and human microbiome project

Owing to such developments and in the field of genomics, a bioinformatics researcher is able to answer the number of questions that are raised in the modern era. In addition to this it has the ability to unlock the doors that were closed between medical science and environmental microbiology for years. For example, pyrosequencing is preferred to be used in studying tumor load, due to multiple advantages, its sensitivity is higher than formal techniques (Sanger) for instance, it needs only 5% of tumor load in a tested sample to do a same job in a cost-effective manner. Even, the number of computer softwares are developed for data analysis yet it involves manual work which increased the chances of human errors. That is why the data analysis for pyrosequencing is most critical steps and demands precision (Shen and Qin, 2012).

Metagenome of different organs of humans

Microbes that reside in the human body are around 100 trillion in number and most of them are present in the intestine. That means microbes depend on us for their survival are 10 times more than our own body cells (somatic and germ cells). Owing to this we possess certain traits which occurs as a result of a symbiotic relationship between microbes and our body. Our bodily needs and function depend on microbes which plays a vital role. Thus, for better understanding of the human health and health related issues, we need to study the role of microbes and their metabolites in human energy metabolism, immune functions, absorption of nutrient and other physiological functions (Backhed *et al.,* 2005; Gill *et al.,* 2006).

Gut microbiome and its significance

The gut microbiome is extensively studied because gut microbiome has been found to play a central role in maintaining homeostasis of the body. The major abnormalities that happen in our brain, heart, musculoskeletal and metabolic process occurs as a result of GI dysbiosis (De Vos & Nieuwdorp, 2013; Lloyd-Price et al., 2016). For example, the *Firmicutes* were found to present in larger numbers in obese individuals than lean while *Bacteroidetes* number plummeted (Ley et al., 2006; Furet et al., 2010).

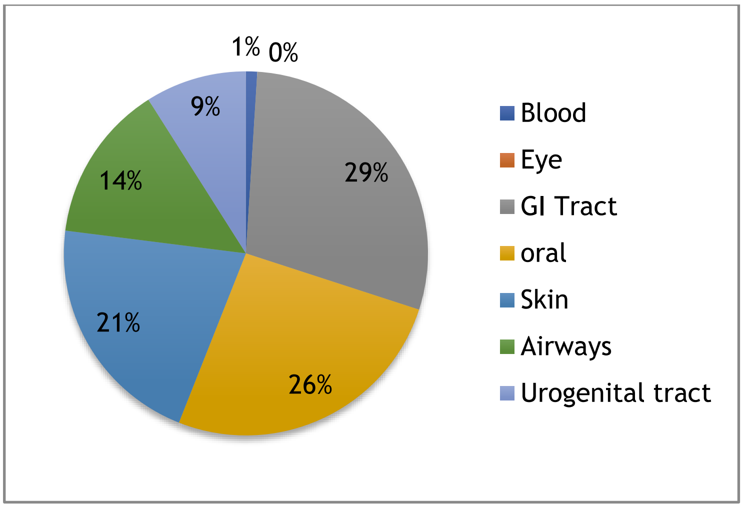

Figure 1: Abundance of bacteria present in different organ sequence in HMP (HMPC, 2012).

2. GI-Stomach Microbiota

Stomach is a vital organ of Gastrointestinal track (GI) that has a peculiar characteristic due to its acidic environment. The microbes that reside in the stomach are unique due to ecological environment that it offers to its inhabitants. This organ connects the upper and lower parts of the GI tract so it has a rich diversity of microbes. But, initially it was thought that the stomach is free of microbes because of its acidic environment but later traditional culture based studies proved it wrong. It possesses acid resistant bacteria such as *Streptococcus, Neisseria* and *Lactobacillus* (Marshall *et al.,* 1984; Monstein *et al.,* 2000). Marshall *et al.,* in 1984 discovered *Helicobacter pylori* that captures the interest of reseachers in studying digestive disease.

The molecular techniques, mainly 16S rDNA further enriches our knowledge by identifying more microbes in the gastric mucosa and those were *Enterococcus*, *Pseudomonas, Staphylococcus* and *Stomatococcus.* Metagenomics together with 16S rRNA offered high throughput sequencing technology identified 128 of phylotypes that comes under 8 different classes and also 1056 non *H. pylori* clones found out. The findings were based on studies done on 23 patients that were suffering from gastric diseases (Andersson *et al.,* 2008; Li *et al.,* 2009).

In general, the GI tract microbiota plays a central part in maintaining homeostasis of the body. The major abnormalities occur in our brain, heart, musculoskeletal and metabolic process occurs as a result of GI dysbiosis. So, the microbes that were explored, helps us to identify the best way to cure diseases (de Vos and Nieuwdorp, 2013).

2.1. Application of microbiome in different perspective

The microbes of diverse population have been studied since from the last few years. The researchers have been studying the microbiome from different perspectives and while seeing different factors that help in shaping and maintenance of microbiome to understand the variability among different individuals. A plethora of knowledge is available based on number of factors that change the normal microbiome to a high-risk diseased microbiome. The factors that contribute the stability or change microbiome are dietary patterns, gender, ethnicity, age, genetics, environmental factors, and some early life events also play a vital part in the formation of one's microbiome (Wade, 2012).

The alteration in the gut microbiome enhances the risk for disease development in a person. For example, the antibiotic consumption changed microbiome composition and increases the chances of disease development because the changes favors the development of pathogen bacteria like *Chlostridium difficile* (Sekirov *et al.*, 2010; Ferreira *et al.*, 2011; Willing *et al.*, 2011b; Wlodarska *et al.*, 2011). The animal studies have been shown that certain microbes presence increased the chances of chronic inflammation (Ferreira *et al.*, 2011; Willing *et al.*, 2011b; Wlodarska *et al.*, 2011) while other microbial population, which is responsible to convert luminal compounds into carcinogens enhances the chances of developing cancer in a person; also showed adverse response against chemotherapy given (Wallace *et al.*, 2010). This shows that the maintenance of microbiome is a key component for the maintenance of one's health or for preparation of one's body for fighting against the alarming situation (Virgin and Todd, 2011).

An integrated approach is applied by researchers in which metagenomics data are compared with meta-transcriptomics, meta-proteomics and meta-metabolomics to clearly define the impaired metabolic pathways that involve in overall disease progression. By having a diverse range of knowledge in the future, researchers would be able to come up with an alternative solution that would help physicians manage diseases in a better way. For example, in case of *C. difficile* infection, it is observed that 40% of patients suffer from a recurrence of disease after taking a standard antibiotic course, which is the conventional form of treatment. But based on the information of gut microbiome a new treatment named fecal microbiota transplantation is introduced that applied by medical professionals. The fecal microbiota of donor installed in the infected individual to cure infection. This therapy not only recover patients' health but it is also observed that the *Bacteroidetes* number of patients after installation of FMT increased and *Proteobacteria* decreased and overall, all microbiota shows more diversity than before transplantation (Seekatz *et al.*, 2014).

Other than this microbiome study provides us information through which new diagnostic tools are expected to design that allows early diagnosis and better treatment. Not only this, but such Integrated approaches are also gold standard in designing personalized medicine by considering physiological parameters along with whole genome and microbiome (Wang *et al.*, 2015). Conclusively, the outcome of gut microbiome research and its correlation with different diseases and treatment is restricted to animal study till date until safety measure to be implemented on humans are formulated such area need vigorous research and stringent guidelines to be formulated to make it effective and safe for humans (Yuan et al., 2021).

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Advances in drug delivery: A Multifaceted collaborative outcome

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During the recent years, drug delivery science has embraced several advancements to improve the bioavailability of poorly soluble active ingredients, site specific delivery and manufacturing routines. These developments are primarily attributed to progresses in materials and manufacturing equipment, improvements in particulate engineering and design of novel formulations.

Various materials of pharmaceutical interest have been developed by crosslinking, polymerization and elimination or addition of functional groups in the existing entities. Physical crosslinking of polyvinylpyrollidone and chemical crosslinking of carboxymethyl starch and methacrylic acid / divinyl benzene copolymer resulted in super-disintegrants namely, crospovidone, sodium starch glycolate and polacrilin potassium, respectively. Copolymerization of esters of acrylic and methacrylic acids yield Eudragit matrix former for sustained release. Deacetylation of chitin resulted in the formation of chitosan, a unique drug carrier, capable of modulating the release of a drug. Inclusion of thiol group to chitosan yielded thiolated chitosan which serves as an efficient mucoadhesive agent. Addition of organosilane to microporous silica resulted in a hydrophobic matrix. Pharmaceutical industry of modern age is using co-processed materials or ready to use excipient combinations to achieve convenient manufacturing with reduced variability. The material scientists are required to coordinate with computational chemists and formulation scientists in order to improve the functionalities of various materials that satisfies the demands of pharmaceutical industry. Furthermore, improvements in manufacturing processes are admissible to obtain better yields, reduce operational cost and product rejections. Several advancements have been reported in the manufacturing equipment, these include design simplification, integration with various technologies, adaptation of continuous manufacturing and inclusion of process analytical tools (Kozarewicz and Loftsson 2018).

A tableting press with simplified design (i.e., comprising five segments and ten segment blocks was introduced to reduce (~70 %) turret setup time, product loss and achieve higher output (~40%), easy cleaning. The manufacturing facilities integrate atomization and freeze dryers to achieve efficient drying of thermolabile products. The concept of continuous manufacturing is appreciable by peers as it offers feedback driven efficient manufacturing, easier scale-up, reduction in variability and lower residence time in a manufacturing plant. Process analytical tools / sensors are installed in the equipments for real time monitoring of the progression of the process, feed-back control of these manufacturing processes and confirming the quality of final product. Nevertheless, a successful design of equipment often demands a robust installation, easy cleaning and maintenance of the machine that is compliant with good manufacturing practice (GMP) (Arshad et al. 2021).

Particulate engineering has been a key consideration in drug delivery as dissolution, a primary determinant of bioavailability, depends upon specific surface. Techniques such as milling, centrifugal spinning, electrospinning, electrohydrodynamic atomization (EHDA) resulting in micro, nano sized porous morphologies are sought to achieve desired product performance. Milling and co-milling has been adopted by the pharmaceutical industry owing to its ease of operation, scalability, and low installation costs. However, drug stability hazards demand suitable alternates. The use of centrifugal spinning has also been reported to obtain fibrous masses showing higher dissolution rates (Nasir et al. 2021). Other techniques commonly practiced for particulate engineering include spray drying and spray freeze drying. Herein, atomization of solution or suspension is coupled with drying of the formed particles in a suitable environment (air drying, freeze dying etc). This technology is used for processing macromolecules, thermolabile and poorly aqueous-soluble agents.

Modern techniques such as Electrospinning, EHDA promise particle size reduction without imparting thermal stress. In EHDA technique, a drug solution or suspension is transformed into particulate systems under the influence of an external electric field particularly 10-25 kV. The resultant particles exhibit uniform size distribution, high surface area-to-volume ratio which remit several fold higher drug dissolution rates and permeability. This technology has been used to prepare particulate systems promising drug delivery to lungs, brain, posterior regions of eyes and skin (A. Ali et al. 2021).

Despite extensive research in the field of dosage form design, many of the medicaments such as vaccines, insulin etc. are delivered as injectables. Barriers associated with the design of oral formulations for these drug substances include denaturation of protein-based sensitive drugs in the gastric environment as well as hepatic first pass effect. In case of parenteral delivery, production of biohazardous sharp waste and non-compliant behavior of patient due to painful skin invasion caused by hypodermic needles makes drug delivery suboptimal. Dosage forms offering painless, self-administrable drug delivery are desirable. In this situation transdermal route is considered a promising choice as it meets the primary requirements of drug administration. However, the conventional patches are somewhat less efficient in delivering macromolecules as the inherent design of intact stratum corneum does not permit permeation of proteins.

The researchers have reported advancement in the transdermal route for drug delivery. The application of exogenous physical principles such as iontophoresis, sonophoresis increase skin permeability by temporarily disrupting integrity of stratum corneum and without damaging deeper skin tissues. Therefore, the penetration of otherwise less permeating polar drugs is improved.

More recently, microneedle based transdermal drug delivery systems capable of piercing stratum corneum and delivering drugs, vaccines and proteins directly into systemic circulation without damaging deeper skin tissues have been reported. Microneedle patches (MNPs) comprise of an array of tiny (25 – 2000 μm) needles. These micron sized needles penetrate skin and administer loaded drug without stimulating pain receptors. MNPs are considered superior to the oral route and conventional hypodermic needles due to their ability to deliver drugs at a desirable rate in a minimally invasive manner. The feasibility of various materials including metal, sugar, polymer, ceramic, silicon and glass for preparing microneedles, with suitable mechanical strength (in terms of capability to breach skin layers and deliver loaded drug), has been extensively investigated (R. Ali et al. 2020). Numerous hydrophilic / polar drugs (e.g., cetirizine), antibiotics (e.g., macrolides, gentamicin), high molecular weight drugs (e.g., heparin sodium, insulin) and intact cells (e.g., T cells, mesenchymal stem cells), otherwise challenging to deliver transdermally, have been successfully delivered by using MNPs (Arshad et al. 2019).

Vaccine delivery (both in liquid and solid form) via skin is reported to be more efficacious as compared to other routes due to the abundance of antigen presenting cells in skin. MNPs have been successfully utilized for delivering BCG, influenza, tetanus toxoid, rabies and COVID-19 vaccines. MNPs offer self-administrable drug delivery which can accelerate immunization programs in resource poor countries, particularly, during pandemics like COVID-19 (Zafar et al. 2020). MNPs have also been used for the administration of diagnostic agents such as tuberculin. MNs have been studied for theragnostic purposes such as diabetes control.

Expansion of operational boundaries of pharmaceutical interest demands a collaborative interaction of professionals working in the domains of material science, computational chemistry, designing of machines, particulate engineering and dosage form design. A higher emphasis on automation of manufacturing techniques and *in-situ* monitoring of different unit operations relating to the manufacturing of particulate systems as well as dosage forms would revolutionize the pharmaceutical industry.

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Agriculture 4.0

Professor Michael G.K Jones, Director (WA State Agricultural Biotechnology Centre, Murdoch University, Australia)

One of the 'grand challenges' of our time is to feed the world's growing population by 2050 and beyond. This must be done in a sustainable manner whilst maintaining the world's biodiversity for future generations, against a backdrop of a changing climate and a desire for a better life by many.

What are the statistics for 2050? An estimated 9.7 billion people, one third of the agricultural land area per person compared to 1961 and 71% more food needed.

Can we rise to this challenge?

I would argue that through sensible use of new science and technology, and enabling government policies, we can achieve these goals. But, if national and international red tape gets in the way, these gaols will be much harder to reach.

On the positive side, there is increasing excitement amongst agricultural researchers that a series of new technologies now becoming available will enable us to reach the 2050 goals. These technologies encompass both new genetic technologies (AgriBio), new physical enabling technologies (AgriTech), and new development in food (FoodTech).

On the AgriBio side, scientific advances include genomics – the complete genomic sequences of all the major crop plants are now available, so that genes that underlie agricultural traits can be identified as never before, and new ways of combining the best traits using speed breeding and molecular markers, transgenic (GM) crops and gene editing (GE) are now being deployed.

Genetically modified (GM) crops, today provide more than 10% of the world's food, are consumer safe, and can provide food with enhanced health benefits. Gene editing, essentially targeted mutagenesis, can deliver many, but not all, of the benefits of GM crops, whilst avoiding the political stigma of GM crops. In many countries GE crops have been de-regulated and can be grown in the same way as conventionally bred (manipulated) crops. There is real excitement about the contributions that GE technologies can make to future food production.

On the AgriTech side, there are equally exciting advances, marrying the power of the internet with GPS and the Internet of Things (IoT), auto-steer agricultural vehicles, robotics, remote sensing, digital agriculture, precision farming and yield mapping. These technologies enable better use of inputs with less waste and run-off, so benefitting the environment.

To these advances must be added hydroponics and vertical farming. Hydroponic growth of plants in a controlled environment, also known as protected farming, allows growth of many food plants all year round under controlled conditions, essential pest free. To this can be added vertical farming, in which automated hydroponic systems established in high rise buildings, use LED lights delivering only the wavelengths that plants need for photosynthesis at the blue and red end of the spectrum (i.e. pink lighting). Vertical farming can deliver 100 times the productivity per unit area of land, using a fraction of the water and nutrients, and solar energy to power the LED lights.

High rise plant production can take place in the centre of major cities, and high-rise vertical farms are already present in conurbations like Tokyo, Shanghai and Dubai, avoiding the need for longer-distance transport of food.

In arid areas, the same strategies can be used to produce agricultural produce from seawater and sunlight – Sundrop Farms in South Australia is a perfect example.

In the FoodTech area, there are major investments to develop plant-based 'meat'. Already major fast food chains are selling plant-based burgers, such as the 'Impossible Burger' and 'Beyond meat' products. Since more than 60% of all beef in the USA ends up as ground beef, this can be replaced by plant-based products. Cell cultured meat, fish and diary products are also in the pipeline, and Solar Foods is developing a food protein ('Solein') from 'thin air', using electricity, water, vitamins and mineral and bacteria. All these technologies aim to produce food or feed products with less water fewer inputs, with a small land footprint. They can be scaled-up massively in the future.

So, essentially, the technology to feed 9.7 billion people in 2050 and beyond is already here. What else is in the equation? The answer here lies in national and international regulations which can limit these developments, and in consumer acceptance and willingness to adapt their diets. The international harmonisation of regulations is one key, since in our interconnected world, foodstuffs are a major transported commodity. If an improved GE or GM product is developed by an exporting nation, importing nations must have the regulations and policies in place to accept them. Included here is biosecurity and minimising incursions of new pests and diseases. This is where 'Science Diplomacy' is needed, where decisions on national regulations and international agreements must be made based on the best scientific evidence, to ensure that the benefits in the pipeline reach the people who will benefit most.

In conclusion, the best science and technology, deployed where needed, can meet the world's demands for food and fibre, whilst still preserving biodiversity and wilderness areas. But this is predicated on the removal of non-tariff trade barriers, and evidence-based regulatory structures, harmonised internationally, the latter to be achieved by Science Diplomacy.

Regulatory Perspectives

Pakistan-China Cooperation: A [Nuclear] Regulator Perspective

Dr. Hamid Saeed Raza, Noreen Iftakhar, Faiza Batool (Pakistan Nuclear Regulatory Authority)

Nuclear regulators worldwide cooperate with each other to enhance safety and security of nuclear facilities. Bilateral collaboration between nuclear regulators helps in sharing knowledge, best practices, learning lessons from each other's experience and building capacity in areas of mutual interests. Pakistan Nuclear Regulatory Authority (PNRA), the national nuclear regulator in Pakistan, cooperates with other nuclear regulatory bodies and international organizations for technical support and capacity building in respect of regulating peaceful uses of atomic energy. PNRA also participates in numerous international activities including international agreements, working groups, standards development committees and peer reviews to enhance nuclear safety & security under the umbrella of IAEA. PNRA has also signed bilateral cooperation agreements with nuclear regulators of other countries. Amongst them, bilateral relationships with number of organizations of China like Chinese nuclear regulatory body namely, National Nuclear Safety Administration (NNSA), its Technical Support Organization (TSO) namely Nuclear Safety Centre (NSC) and China Nuclear Power Operation Technology Corporation (CNPO) is noteworthy.

This paper highlights cooperation between PNRA and Chinese organizations and also provides details about the areas of cooperation in the domain of nuclear safety. The outcome of this cooperation is also described which signifies that this cooperation has strengthened PNRA's capabilities for effective regulatory oversight thereby ensuring safety and security of nuclear power program of Pakistan.

1. Genesis of Pak-China Nuclear Cooperation

Since the establishment of diplomatic relations in May 1951, Pakistan and China enjoy close friendly relations. These friendly relations, spanning over the years, resulted in bilateral cooperation in various domains. The cooperation between China and Pakistan in nuclear field evolved in 80s when both countries signed Nuclear Cooperation Agreement in September 1986. Under this agreement, China committed to provide nuclear power reactors and associated products and services to Pakistan. Under this accord, Pakistan Atomic Energy Commission (PAEC), the operator of nuclear energy in Pakistan, signed an agreement with China National Nuclear Corporation (CNNC) on 31st December 1991 for the construction of a 300 MWe PWR nuclear power plant at Chashma, District Mianwali. Meanwhile, Directorate of Nuclear Safety and Radiation Protection (DNSRP), at that time a part of PAEC, also signed a protocol with National Nuclear Safety Administration (NNSA) of China in April 1992 for cooperation in the field of nuclear safety. Under this protocol, an agreement was signed in 1992 between DNSRP and Beijing Nuclear Safety Centre (BNSC) for providing assistance in the safety review of CHASNUPP Safety Analysis Reports and regulatory inspections during manufacturing of equipment. BNSC[80] also committed to arrange training courses for regulatory personnel. This protocol was valid for five years and subsequently extended in 1997.

With the establishment of independent regulatory body as PNRA in 2001, it inherited and honored all the international commitments made by its predecessor DNSRP. In 2004, an arrangement was signed between PNRA and NNSA of China under the Protocol to establish a Steering Committee. Each side designated senior level official as "Coordinator" with the responsibility to exchange information and ensure implementation of the activities identified by the Steering Committee. The Steering Committee holds periodic meeting, alternatively in China and Pakistan. More specific cooperation agreement between Technical Support Organizations (TSOs) namely i.e., Center for Nuclear Safety (CNS) of PNRA and Nuclear and Radiation Safety Center (NSC) of NNSA of China was signed in September 2004 and subsequently renewed in June 2009, May 2014 and September 2019.

Another important agreement was signed between CNS-PNRA and Research Institute of Nuclear Power Operation (RINPO)-China[81] for cooperation in the field of training in ISI/PSI, information exchange and development of NPP equipment models. PNRA and China Nuclear Power Operation Technology Corporation limited (CNPO) entered into bilateral agreement in 2008 to provide technical support to PNRA in research and development, review & assessment, and licensing of manufacturing facilities. This was initially valid for ten years and was extended for another ten years in 2013. PNRA has also signed an agreement in August 2010 with Department of Nuclear Science and Technology of Xi'an Jiaotong University of China to provide education and training,

[80] Beijing Nuclear Safety Centre (BNSC) was later renamed as Nuclear and Radiation Safety Center (NSC).
[81] RINPO was later renamed as China Nuclear Power Operation Technology Corporation limited (CNPO).

research and development and information exchange to PNRA professionals in the areas of nuclear safety assessment. The Northern Regional Office (NRO) is the inspection organization of NNSA, responsible for inspections to ensure safety and radiation protection of civil nuclear installations, especially in manufacturing of nuclear safety equipment. PNRA also signed agreement with NRO in April 2011 to strengthen inspection methodologies.

To sum up, nuclear regulator in both countries are connected through various cooperation agreements which resulted in exchange of experience and strengthening PNRA capabilities in regulation or regulatory oversight of nuclear power program.

2. Areas of Cooperation

The cooperation agreement between PNRA and its Chinese counterpart covers many areas of mutual interests. Subsequent paragraphs provide details of areas of cooperation and associated activities being performed.

2.1 Strengthening Review and Assessment Capabilities

BNSC contribution in providing assistance to DNSRP for safety review of CHASNUPP (C-1) license application is worth mentioning. BNSC adopted the same methodology used for licensing of nuclear power plants in China during the safety review of C-1. The review of C-1 license application was carried out by joint teams of BNSC and DNSRP. However, BNSC experts extended full cooperation in review of C-1 licensing submissions including Codes & Standards, Preliminary Safety Analysis Report (PSAR) and Final Safety Analysis Report (FSAR) and associated programs (i.e. Quality Assurance Program, Commissioning Test Program and In-service Inspection Program). BNSC experts also supported DNSRP in the review meetings of CHASNUPP project and resolution of review queries. Regulatory professionals learnt a lot during the review meetings held between regulator, licensee and designer. This enabled improvement in documentation of licensing submissions, enhanced understanding and applicability of codes and standards. Moreover, BNSC also supported DNSRP in capacity building of its personnel by offering attachment/working with NNSA/BNSC experts in Beijing. Figure-1 shows the number of joint review meetings and number of PNRA officers participated in these meetings.

Figure 1: Number of Joint Review Meetings and Officers Participated

2.2. Enhancing Regulatory Inspection Capabilities

With the intent of promoting cooperation, BNSC provided technical support to DNSRP in different dimensions of nuclear safety inspections of important safety related mechanical and electrical components during construction, manufacturing and installation. BNSC adopted the same methodology used for nuclear safety inspections of nuclear power plants in China during the inspection assistance to CHASNUPP. BNSC further broadened its technical assistance for the development of inspection related documentation including quality assurance and safety inspection program of CHASNUPP project. BNSC also supported DNSRP in enhancing the understanding of inspections related activities starting from how to conduct inspections, also covering development of inspection methodology, review of test procedures, review of non-conformances reports and verification of implementation of QAP. BNSC also played a key role in the capacity building of DNSRP inspectors by arranging specific training courses and involved them in nuclear safety inspections of CHASNUPP project. DNSRP inspectors also participated as observers in various inspections in China during on-the-job training which proved helpful later during the regulatory oversight of nuclear installations. Figure-2 reflects number of joint inspections and number of PNRA officers trained for enhancing regulatory inspection capabilities.

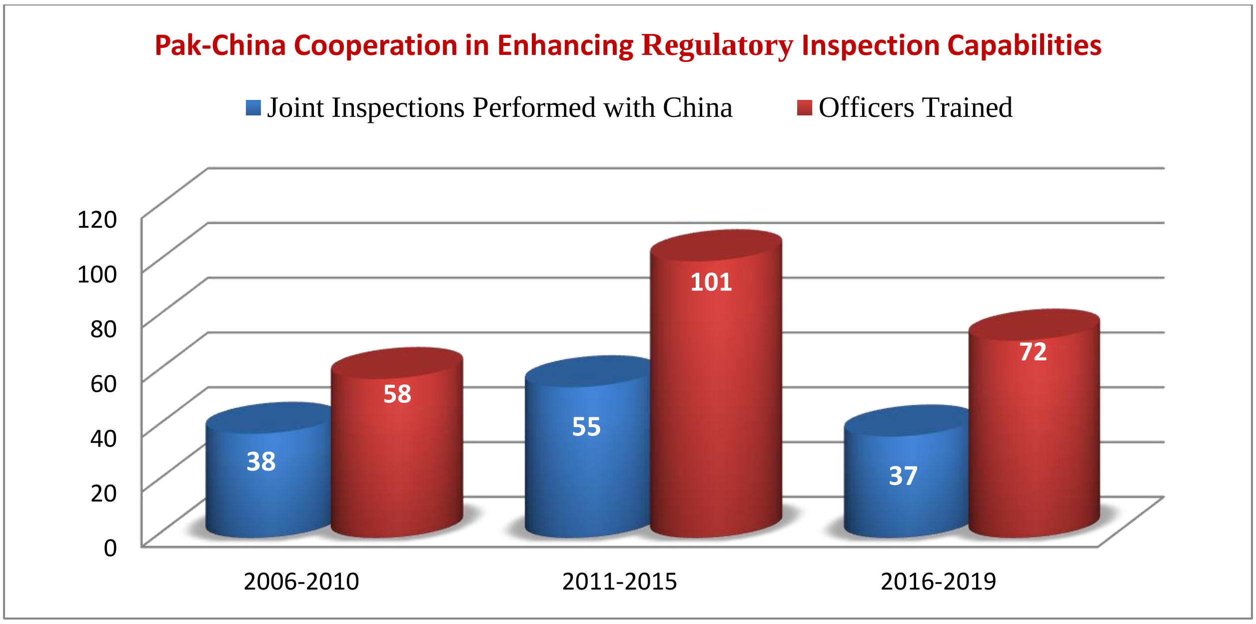

Figure 2: Number of Joint Inspections and Officers Trained

2.3 Assistance in Licensing of Nuclear Equipment Manufacturing Industry

Cooperation between PNRA and NNSA was further extended to licensing of safety class equipment manufacturers. NNSA supported PNRA in review and assessment of the submissions made with licensing application of equipment manufacturers and also assisted PNRA in the inspections of safety class equipment manufacturers on the basis of Chinese experience and practices for licensing of manufacturer of nuclear grade pressure retaining component.

Furthermore, PNRA Inspectors were placed in North Regional Office (NRO) of China for on-the-job training in inspections of manufacturers of safety class (mechanical, electrical and I&C) equipment. The placements enhanced PNRA inspector's capabilities in inspections methodologies, strategy, codes and standards etc. by learning from Chinese experiences and practices through participation in inspections along with NRO inspectors.

In addition, NNSA experts visited Pakistan to provide assistance in licensing activities of HMC-3 which contributed in the capacity building of PNRA personnel in review & assessment, inspection and licensing methodology, inspection of processes such as material testing, welding, Non-Destructive Testing (NDT), functional and qualification tests through workshops and training courses. Furthermore, Chinese experts also supported PNRA in detailed inspection/audit (process documents review, workers interview, and workshop visit and process witness) of safety class equipment manufacturers in Pakistan. These activities proved very beneficial later for regulating and overseeing nuclear safety class equipment manufacturers in Pakistan.

2.4 Competence Development through Trainings and Associated Activities

Under the agreement signed between DNSRP and NNSA in 1992, DNSRP personnel benefited by developing competence through training courses arranged in the field of nuclear safety, scientific visits in Chinese centers and establishments pertaining to nuclear safety related matters, exchange of experts, scientific and technical personnel to participate in seminars, symposiums and other activities related to nuclear safety.

Under the Pak-China cooperation on national NPP program development, DNSRP officials attended plant operation training in China for around three (3) years. In this training, officials were provided class room training on NPPs systems and were also trained on Full Scope Training Simulator (FSTS) for understanding of plant response in different situations. These officials qualified Main Control Room (MCR) licensed operators examination.

Moreover, China also provided assistance to PNRA officials in learning Chinese language. By overcoming language barrier, PNRA officials were able to communicate during negotiation and discussion with Chinese counterparts. Subsequently, PNRA officials were placed at Regional Offices of China, CNPO and Nuclear Safety Centre (NSC) for joint activities. The attachments at NSC, Beijing enhanced the capacity building of PNRA officers in the domains of review & assessment and analysis. The competence development in the area of review & assessment and analysis remained beneficial for in-depth understanding of design of NPPs and skill development for verification of analysis submitted by licensee. These activities supported PNRA in performing regulatory activities of review and assessment of licensing submissions of future NPPs.

As per agreement between PNRA and CNPO, cooperation was provided for the development of physical models of nuclear power plant components and trainings. PNRA also signed long-term cooperation agreement with CNPO, with the validity of 10 year, for cooperation in training, consultation, scientific research, information exchange, development and technical support for nuclear power plant safety. PNRA officers were trained at CNPO in the areas of NPP systems, design engineering, safety analyses and in-service inspections. CNPO also extended its support for design and manufacturing of models of key components of PWR equipment such as Reactor Pressure Vessel, Steam Generator, Pressurize, Reactor Coolant Pump, Turbine, and Fuel Assembly. Figure 3 illustrates competence development events and number of PNRA officer participation in these activities.

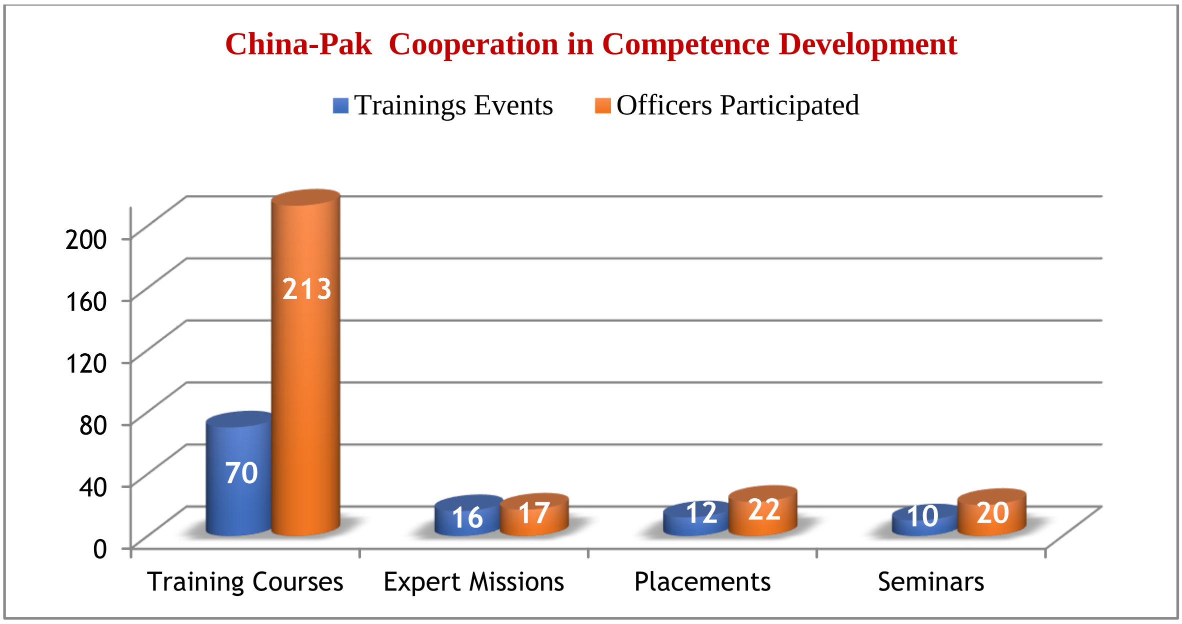

Figure 3: Number of Training Events and Officers Participated

3. Outcome of Cooperation

Pak-China regulatory cooperation has been beneficial for PNRA in following ways:

3.1 Strengthening Technical Competence of PNRA Personnel for Performing Regulatory Activities Indigenously

China supported in strengthening regulatory infrastructure of PNRA by assisting in review and assessment, regulatory inspections, on-the-job training and training in specialized disciplines through placements & attachments of officers at technical support organizations & regulatory body of China, participation in seminars, training courses and workshops. Chinese Counterpart also provided hands-on training of software used in the safety analysis report. This training added confidence to PNRA officials to perform independent audit of the analysis provided as a part of the licensing submission. These activities collectively contributed in enhancement of competence development of PNRA.

3.2 Saving Foreign Exchange

China has extended its full cooperation during the licensing process of C-1. However, this was an example of the regulatory dependence on regulator of the vendor country. In addition, this involved significant expenditure in foreign exchange payable as expert services of Chinese regulators. However, this cooperation led to capacity building of regulatory staff in specialized technical disciplines. This enabled PNRA to establish its internal technical support organization i.e. CNS for performing safety review and audit safety analysis of licensing submissions to support licensing and regulatory decision making process of PNRA. Now, PNRA is in a position to perform the regulatory activities independently with all the relevant expertise developed within PNRA. Starting from C-2 Safety Analysis Report (SAR), the indigenous capability enhanced day by day which enabled PNRA for independent regulatory decision making as well as saved large amount of foreign exchange. This greatly reduced reliance on external support and saved valuable foreign exchange.

Subsequently, PNRA competence development is reflected in independent regulatory decision making of licensing of Chashma Nuclear Power Plants Units-3 and 4 as well. As per evolution of advance nuclear regulatory requirements, safety assessment of these two projects was a challenge because some requirements were further strengthened based on the new versions of codes and standards. However, PNRA remained successful by utilizing its ultimate efforts to ensure that safety of C-3 and C-4 is enhanced through verification of necessary improvements in design as per international standards. PNRA experience of C-series plants was utilized in licensing of K-2/K-3 projects, licensing of designers and equipment manufacturers and of nuclear safety class equipment, certification of transport packages & spent fuel cask and licensing of radioactive waste management facilities & spent fuel storage facilities.

3.3 Provision of Support to Embarking Countries under IAEA Ambit

Over the years, PNRA earned a respectable name at international level by contributing in various international activities specially in providing assistance to embarking countries under the ambit of IAEA in strengthening their regulatory infrastructure. Currently, PNRA is in position to provide assistance to embarking countries for the capacity building of its technical staff in performing core regulatory functions under the IAEA umbrella. Furthermore, PNRA experts also played a key role in development of IAEA safety and security standards.

Conclusion

PNRA believes that collaboration with international community is important for competence building, knowledge sharing and strengthening its regulatory framework to ensure safety and security at nuclear installations and radiation facilities. PNRA maintains a good cooperation and interaction with international organizations and regulatory bodies of other countries for technical and scientific support with objective to strengthen organizational capabilities for an effective regulatory oversight.

National regulator is benefiting from bilateral relationship being established with NNSA of China since 1992. PNRA inherited this relationship with NNSA after its establishment in 2001 and continued seeking assistance and scientific support in regulatory domains. The support includes review and assessment of licensing submission of NPPs and manufacturers of safety class nuclear power plant components. It has supported PNRA to strengthen its review and inspection capabilities. It has also helped PNRA in building capacity of personnel in different technical areas through placements at its offices, training courses and workshops. As a result of successful cooperation, PNRA is capable to perform activities related to regulatory oversight independently.

Thus, it can be acknowledged that China has assisted Pakistan in competence development of indigenous for regulatory oversight which is essential to ensure safe and secure nuclear power program of Pakistan.

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Regulation Approach for Geo-Engineering Technologies

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Climate change and food security are at the centre of key global challenges that states must actively resolve to ensure sustainability and species survival. Both issues are interacted upon and are also exacerbated by negative activities like pollution and carbon intensive industrial expansion. To add to the issue, human population is expected to rise to about 10 billion by 2050, which will undoubtedly place immense pressure on food systems. In this backdrop, in the recent past various technologies have matured or are under evolution that can potentially enable societies to tackle the dual threat through climate/ geo-engineering. As is the case with such ecosystem altering technologies (such as the development of biotech crops/ livestock), social acceptance and economic considerations are key driving factors for commercial outcomes.

Conventional geoengineering technologies include negative emissions technologies which enable decarbonization by removing CO_2 from atmosphere and storing it in biological reservoirs. Another spectrum of technologies includes devices for solar radiation management which can reflect sunlight back into the space. It is also possible to modify and/or edit plant, animal, and potentially human genomes to sustain climatic stress. With the advent of gene editing, the process has been made considerably less time and cost intensive.

The scientific basis for the development of geo-engineering technologies stems from the fact that keeping global warming levels well below the 2°C threshold requires a rapid transition towards net zero emission by 2050. However, simulated scenarios show that some emissions are difficult to mitigate and thus require geo-engineering enabled solutions. The case for such technologies is also based on the 'carbon debt' argument which posits that decarbonization approaches can buy some time needed for the net zero transition process. Lastly, uncertainty in the climate change cycles may require such approaches to be deployed on an emergency basis.

As is the case with frontier technologies, the status of geo-engineering/ weather manipulation technologies is mired in complex socio-technical debates. The end goal of using solar geoengineering efforts is crucial to understand its policy impact. From the perspective of science, the potential of the process is clear in reducing climate change impacts. However, the issue of climate change is a sum of many other policy processes and also a subset of collective global policy action (or inaction). If the notion of scientific certainty is brough in, it further complicates the process since current epistemic knowledge about climate response and impacts is not holistic to enable societies to make an informed choice[1].

Furthermore, as is the case with the availability-affordability-accessibility paradox and trade-off of other technologies, it will lead to major ethical discussions. There is also the potential of the technology becoming a source of conflict between countries due to

[1] Cherry, Todd L., Steffen Kallbekken, Stephan Kroll, and David M. McEvoy. "Does solar geoengineering crowd out climate change mitigation efforts? Evidence from a stated preference referendum on a carbon tax." *Climatic Change* 165, no. 1 (2021): 1-8.

asymmetry in governance approaches[2]. Thus, a careful sociotechnical consideration is required.

Despite host of peer-reviewed papers and a range of high-level scientific conferences on solar geoengineering, a great deal of questions about its feasibility and outcomes remains unanswered. But one thing has become increasingly clear: The costs of its implementation would be relatively cheap. It is expected that a few billion dollars a year expenditure could help to offset climate damages in the trillions of dollars.

Solar geoengineering can be potentially powerful and is, in fact, completely altering the way we see the usual economics of climate change: while the benefits are reaped by the entire world population, the costs are borne by those that are cutting their emissions. This leads us to a classic "free rider" issue, where no one wants to go first unless are compelled by policies like carbon taxes or green subsidies. Also, countries incentivise by free riding on the actions of others, which is why steps such as the 2015 Paris Agreement, that try to persuade signatories to do more than they otherwise would, are so essential. Solar geoengineering, on the other hand, reverses this logic which Wagner and Weitzman call the "free driver" problem: The trouble would not be to persuade countries to deploy aerosols but convincing them to stop doing too much too soon. There is a wide consensus that in absence of international agreements, the countries determined to do the most might just end up getting their way. Therefore, there is a need for prudent regulation approach for geo-engineering technologies. The onus of regulation or a potential moratorium rests on the United Nations.

In terms of comparison, the commercialisation of biotechnology and its global regulation provides a good template and reference point to discuss the status of climate altering technologies. Presently, the regulation of biotechnology at the UN level is done through varied conventions and protocols, depending on the end-use. For instance, the Cartagena Protocol discusses the environmental release of modified organisms and their regulatory status. The Sanitary and Phytosanitary Measures under the WTO regime provides trade related guidelines for export of biotech products. Similarly, the Biological Weapons Convention provides a rubric for avoiding weaponization of biotechnology and supports peaceful uses. In addition to these conventions, there has been a policy continuum among countries to support the growth of the biotechnology industry. This ranges from the liberal regime in the North Americas to the restrictive approach in the European Union. There are numerous socio-technical narratives underlying the kind of regulation such as the solutionist approach or the need for precautionary principle.

Despite the recent impetus on climate and energy policy futures, climate engineering has been around for a while. The 1976 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Technologies was borne directly out of climate modification attempts during the Vietnam War.

In the case of climate altering technologies, a similar approach is needed. There is need to acknowledge the dynamic science-policy-society interface at the heart of the debate on a

[2] Baum, Chad M., Sean Low, and Benjamin K. Sovacool. "Between the sun and us: Expert perceptions on the innovation, policy, and deep uncertainties of space-based solar geoengineering." *Renewable and Sustainable Energy Reviews* 158 (2022): 112179.

potential ban or regulated use. Under the auspices of the United Nations, the IPCC has done exemplary work in generating science advice for countries to understand the severity of the climate change issue and the level of mitigation required. It is possible to expand the scope of the UNFCC and the UN Convention on Biodiversity to initiate discussions on the potential regulation of geo-engineering. A ban would be counterproductive and will also lead to lopsided economic outcomes for different countries. To this end, the following approach can be adopted:

a) Drafting the Evidence: the IPCC can be tasked to collate information on the current development and mitigation potential of geo-engineering technologies. This will help create the science advice necessary to take subsequent policy decisions. The report should adequately reflect the scientific processes involved as well as the socio-economic considerations.
b) Creating Consensus: Discourse platforms such as COP can provide an impactful platform to discuss the status of geo-engineering technologies. Similar to how the discussions on biotechnology products have evolved under the Cartagena Protocol and how ongoing discussion on cybersecurity under the Open-Ended Working Group on ICT Security at the First Committee are progressing, this will help generate a global consensus.
c) There is also the need to actively discuss technological developments under the Environmental Modification Convention, London Protocol, Paris Accord etc.

Any potential regulatory system should discuss the following areas:

1. Carbon sequestration and storage: Exploring new ways to remove and store carbon from the atmosphere using innovative technologies and to look at ways in which it can be used as a resource. For example, Graphene production: carbon dioxide is used as a raw material to produce graphene, which in turn is used to create screens for smart phones and other technology devices. Although, Graphene production is specific to certain industries, it is an example of how to use carbon dioxide as a resource as well as a solution in reducing emissions from the atmosphere.
2. Forestry and Land Use: Looking into potential adaptation options to minimize the impact of climate change on carbon stocks in forests and agricultural soils and how these technologies will impact crop management and soil integrity.
3. Avoiding dual use: Policymakers to look at ways to reform trade barriers, such as export controls, so that vital dual-use technologies necessary to combat climate change can be distributed around the world without compromising national security.
4. Deployment: how would the technologies be deployed such as through high altitude aircrafts, sensors, injectors etc.?
5. Markets: expanding the scope of discussion of the carbon economy including emissions credits, water markets, intellectual property, and patents.
6. Social consideration: Finding out ways that can address the ethical aspects of use of geoengineering technique

Towards a Science Diplomacy Typology for Regulation of Agricultural Biotechnology

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The United Nations organized a Food Systems Summit (23-24 September) to discuss the future of global food systems, especially on attaining the zero-hunger target. The Summit is the latest effort to provide a science-policy-society interface to actualize innovative solutions for delivering progress across all UN Sustainable Development Goals (SDGs). Through the adoption of a 'food systems' approach, the Summit has tried to address the entire supply chain, and the potential suite of solutions[1] on offer. Science diplomacy (SD) also represents a sum of efforts to provide socio-technical platforms that can potentially deliver technology enabled sustainable development.

With its diverse molecular toolkit and evolving innovative techniques for value chain improvement, agricultural biotechnology can help address challenges related to health and food security, and climate change. As is the case with other rapidly evolving technologies, evidence-enabled regulatory regimes are vital for avoiding institutional drift[2] and trade barriers. The current landscape of agricultural biotechnology regulations is impacted by a trans-Atlantic divide[3], disharmonized global institutional capacity, ambiguities over the status of gene-edited products, subjective approach to socio-economic considerations[4], and definitions of risk. Over the years, agri-biotechnology has flourished tremendously, and now with the advent of gene editing, scientists can precisely add beneficial properties. However, regulations have not kept pace with technological improvements, adversely impacting the potential of agri-biotechnology to contribute to sustainable food systems.

While the overarching concept of SD refers to the interface of global science and international relations, its fluid taxonomy[5] ranges from a 'solutionist' approach to a state driven approach to advance national needs and address cross-border interests.

This perspective piece expands on the role of SD as a platform[6] and proposes a three-tiered approach to improving regulatory outcomes related to agri-biotechnology at the level of process, products and education. The products include the organisms and traits that have

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been improved through the use of biotechnology, such as the development of stress tolerant crop varieties [7] or reducing allergenicity of wheat through gene editing[8].

a) Process

There are at least nine different conventions/protocols within the UN based multilateral order regulating different aspects of biotechnologies. For instance, the Cartagena Protocol on Biosafety to the Convention on Biological Diversity[9] regulates the environment-related impacts, whereas the International Plant Protection Convention overseen by the Food and Agriculture Organization of the UN deals with plant health and handling the spread of plant pests. These Conventions/Protocols are rich interfaces of science-policy interaction and feature science advice structures, but the impact remains to be optimised. One crucial missing link is a cross treaty engagement mechanism to harmonize essential aspects, such as definitions related to new biotechnologies (gene editing) and risk regulatory standards. There is also the issue of treaty conflict (Cartagena and WTO Phytosanitary Measures), leading to a regulatory deadlock[10]. SD can be an enabler here through cross-sectoral treaty dialogues and optimal utilisation of available science advice mechanisms. This also would have a direct impact on increasing national capacities in devising regulatory guidelines related to agri-biotechnology.

[7] Menz, Jochen, Dominik Modrzejewski, Frank Hartung, Ralf Wilhelm, and Thorben Sprink. "Genome edited crops touch the market: a view on the global development and regulatory environment." *Frontiers in plant science* 11 (2020).
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Figure 1. International regulatory regimes related to biotechnologies dealing with various aspects. Different regimes under the UN System providing regulatory rulings, advice and norms related to the use of biotechnology.

b) Product

Agri-biotechnology can deliver a wide range of deliverables and products ranging from biopesticides to stress-tolerant plants. Agri-biotech products globally have been regulated through the development of individually legislated biosafety frameworks by several countries. In many instances, the national legislation are guided[11] by multilateral texts such as the Cartagena Protocol. At the heart of these frameworks is the notion of health, food, and environmental safety or risk assessment. Similar to the contentious definition spectrum, there is no international agreement on what 'regulatory trigger' to use for biotech products. Presently, there are two primary triggers: process- and product-oriented[12]. Process-oriented triggers regulate the entire process of producing biotechnology products, whereas the product-oriented trigger focuses on the product's characteristics and traits. SD can potentially help diffuse this binary and provide a science- and society-centred discussion platform. This aspect is crucial because asynchronicity in regulation impacts small farmers/industry access to beneficial uses of new breeding technologies and

[11] Falck-Zepeda, Jose Benjamin, and Patricia Zambrano. "Socio-economic Considerations in Biosafety and Biotechnology Decision Making: The Cartagena Protocol and National Biosafety Frameworks." *Review of Policy Research* 28, no. 2 (2011): 171-195.
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reduces democratization. The success of such an approach would also be dependent on reducing interpretive and framing gaps between producers and regulators.

c) Education

Deliberations and discourse surrounding new and emerging technologies is impacted by misinformation and a lack of effective science communication. Deliverables of SD in the form of negotiation simulations and SD trainings are critically important in bringing together diverse stakeholders and facilitating engagement. We have also trialled a negotiation simulation named the 'Biotech Game'[13], which is centred on role play of the Cartagena Protocol on diverse audiences (n=250 to date) with positive outcomes. Pre- and post-activity surveys show a significant change in perception and understanding of international treaties and biotechnology. The supply side (SD practitioners, academia, and industry) of SD training also enables science communication of new and emerging technologies. This aspect can be sufficiently incorporated into regular STEM curricula to create global technology communication-related discourse. SD as science communication also overcomes the 'deficit model'[14] and expands the participatory landscape for audiences. The education side of SD also determines various 'socio-technical futures' by providing concerned stakeholders with the best evidence to make informed decisions.[15]

Conclusion

Effective use of SD and its deliverables can help attain a sustainable regulatory landscape at the global level related to new and emerging technologies (such as gene editing). Agri-biotechnology can play a significant role in the security of global food supply chains if countries can work towards the harmonization of regulatory standards. The three-tiered approach of process, product, and education provides a directionality towards achieving this goal.

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Cyber Security Challenges in Pakistan: An Assessment

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The recent hacking of the Federal Board of Revenue (FBR) system, which resulted in the leakage of confidential data on the dark web, has once again raised questions on the effectiveness cybersecurity response system in Pakistan [1]. However, it's not a new incident. In January 2021, Sophos Labs *(A private cyber threat intelligence firm)* report made some extremely alarming revelations[2]. According to the report, there are trojanized versions of Android Apps and websites such as the Pakistan Citizen Portal App, published by the Government of Pakistan on Google Play Store. These sites and apps contain malware to steal and exfiltrate sensitive data and information such as CNIC numbers, passport details, usernames, passwords of Facebook accounts, can also read private messages, GPS data, and record phone calls. Hackers deployed the torjanized versions of legitimate apps and websites for the cyber espionage and covert surveillance of Pakistani citizens. Since its introduction in the early 1990s, the Internet industry has progressed rapidly[3]. Pakistani society has gradually built up its footprints in cyberspace and resultantly its dependence on Information and Communication Technologies (ICT). However, despite this increasing reliance on ICT platforms, Cyber Space is still ungoverned and poses a multitude of challenges to the national security of Pakistan. Hostile agencies are taking full benefit of the unguarded cyberspace of Pakistan to undermine the national security of the country. *EU DisinfoLab* report is a case study example of such targeted online campaigns against Pakistan[4]. Rising cyber-attacks against the government and private websites, fake news, targeted disinformation campaigns, phishing attacks, Denial of Service (DoS) and Distributed Denial of Service (DDoS) attacks are some facets of cybersecurity challenges confronted by the State.

The above-cited reports are just the tip of the iceberg. In reality, the Cyber Space of Pakistan is more prone to disruption than reported. Lack of coordination among the key stakeholders and the absence of cyber hygiene in public and private sectors are making the situation more complex and demanding urgent attention of the concerned quarters.

Overview of Existing Cybersecurity Ecosystem in Pakistan

The following table depicts the main contours of the cybersecurity ecosystem in Pakistan.

Legal Framework	• Pakistan Telecommunication Act (1996) • Electronic Transaction Ordinance (2002) • Prevention of Electronic Crime Act (PECA) (2016)

[1] "Indian Hackers behind Attack on FBR Website: Tarin - Business Recorder," accessed October 6, 2021, https://www.brecorder.com/news/40119330.

[2] "New Android Spyware Targets Users in Pakistan," *Sophos News* (blog), January 12, 2021, https://news.sophos.com/en-us/2021/01/12/new-android-spyware-targets-users-in-pakistan/.

[3] Useful Links, "History of Internet in Pakistan," *Ispak* (blog), March 19, 2020, https://ispak.pk/history-of-internet-in-pakistan/.

[4] "Indian Chronicles: Deep Dive into a 15-Year Operation Targeting the EU and UN to Serve Indian Interests," *EU DisinfoLab* (blog), accessed July 11, 2021, https://www.disinfo.eu/publications/indian-chronicles-deep-dive-into-a-15-year-operation-targeting-the-eu-and-un-to-serve-indian-interests/.

	• Protection (Against Online Harms) Rules, 2020
National Strategy Documents	• National Cybersecurity Policy 2021 • Personal Data Protection Bill 2021 (*Under Review*)
National Computer Emergency Response Teams (CERTs)	No
National Cybersecurity Agency	No
National Cybersecurity Guidelines / Standards	No
Data Security, Data Integrity, and Data Localization Requirements	No
Cybercrimes Prosecution Agency	NR3C (works under FIA)
National Cybersecurity Coordinator	No
Cyber Threat Intelligence Agency	No
Capacity Building Institutions	National Cybersecurity Center, Islamabad
Foreign Collaborations	No

After analyzing the information given in the above table, it is not very difficult to discern that key components of a robust and agile cybersecurity infrastructure such as national cybersecurity agency, CERTs, data protection, and cybersecurity guidelines, are missing in Pakistan. Moreover, the legal regime in Pakistan only addresses the cyber-crimes not enough to build a robust cybersecurity mechanism. On 27 July 2021, after long deliberations the Federal Cabinet approved the first National Cyber Security Policy 2021[5] . However, another key document namely Personal Data Protection Bill 2020[6], formulated by the MoITT, is under consideration. The National *Cyber Security Policy 2021* aims at developing a secure and resilient cybersecurity infrastructure in Pakistan. The second draft document, *Personal Data Protection Bill 2020,* is also a need of time which once approved, will be addressing the issues of data security, data integrity, and data localization.

<u>An Evaluation of Pakistan's Cyber Readiness</u>

Pakistan is increasing its reliance on the internet for service delivery and good governance, while the absence of robust cybersecurity infrastructure makes it extremely vulnerable to cyber threats. Further, the country is continuously confronting a hostile regional and international geopolitical environment.

The 2020 Global Cybersecurity Index (GCI)[7] of ITU (International Telecommunication Union) ranks Pakistan at 79 out of 193 Member States. The same index places India at 10th, Bangladesh at 53^{rd,} and Iran at 54th position respectively. GCI Index maps the 193 Member State cybersecurity commitments across five pillars which include *Legal measures*, *Technical measures*, *organizational measures*, *capacity development*

5 "National CYBER SECURITY POLICY 2021," 2021, 15.
6 Member It and Syed Junaid Imam, "PERSONAL DATA PROTECTION BILL 2020," n.d., 32.
7 "Global Cybersecurity Index," ITU, accessed July 12, 2021, https://www.itu.int:443/en/ITU-D/Cybersecurity/Pages/global-cybersecurity-index.aspx.

measures, and *cooperation measures.* It means the legal, technical and organizational infrastructure of Pakistan is the weakest in the region to address cybersecurity threats.

Greater data sharing, increasing social media presence and usage of digital payment platforms and E-Commerce portals are signaling the rapid digitization of the country. As of May 2021, there are 183 Million Cellular subscribers (83.85% Penetration), 99 Million 3G / 4G subscribers (45.04% Penetration), and 101 Million Broadband subscribers (46.36% Penetration) in Pakistan[8]. Such an increasing number of internet and mobile users create both opportunities and challenges for the State to keep its cyber frontier protected. Pakistan's cyberspace is subjected to continuous attacks by both State and Non-State actors. In 2019, senior Pakistani officials become a target of Israeli-origin spyware called "*Pegasus*"[9]. In March 2013, former CIA contractor Edward Snowden made a revelation that Pakistan is under constant digital surveillance by the U.S. National Security Agency (NSA)[10]. In September 2020, K-Electric came under attack of Netwalker ransomware. This attack paralyzed the online service delivery system of the company. The hackers demanded 7 million USD ransom, upon refusing they leaked around 8.5 GB of private data of consumers on Darkweb[11]. Moreover, recently Advisor to the PM on National Security during a press conference claimed that India targeted the critical investigation infrastructure in Pakistan soon after the Lahore bomb blast. He said that *"thousands of attempts of cyber-attacks against our critical investigative infrastructure right after this attack on the 23rd June in Lahore"*[12].

Pakistan has a weak legal regime for countering cyber threats. PECA 2016 covers only cyber crimes, not all aspects of cybersecurity. Likewise, the National Response Center for Cyber Crime (NR3C), which works under (FIA), is resource-constrained and doesn't have the required skills to protect the critical national infrastructure against cyber threats.

Capacity building and creating necessary cyber hygiene both in the public and private sectors is nonexistent in Pakistan. There are no defined protocols and standards for the management of critical data in federal ministries and divisions. Recent leaks of confidential government documents on the internet and social media are because of the absence of such protocols and standards. It is observed that private sector entities design, manage, and host the official websites belonging to federal and provincial ministries and departments. For example, a private entity Interactive Media[13] designed and developed the official website of TCP (Trading Cooperation of Pakistan)[14].

The concepts of data integrity, data sovereignty, and data localization are alien in Pakistan. Critical personal data of Pakistani Citizens like CNIC details, addresses can be

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[8] "Telecom Indicators | PTA," accessed July 11, 2021, https://www.pta.gov.pk/en/telecom-indicators.

[9] "What Is Pegasus Malware? A Definition from WhatIs.Com," accessed July 11, 2021, https://searchsecurity.techtarget.com/definition/Pegasus-malware.

[10] Reuters, "NSA's Mass Surveillance Programme Exposed by Snowden Was Illegal, Rules US Court," DAWN.COM, September 3, 2020, https://www.dawn.com/news/1577715.

[11] "8.5 GBs of K-Electric Data Dumped Online After It Failed to Pay $7 Million in Ransom," accessed July 11, 2021, https://propakistani.pk/2020/09/30/8-5-gbs-of-k-electric-data-dumped-online-after-it-failed-to-pay-7-million-in-ransom/.

[12] "Indian Intelligence Agency Involved in Johar Town Blast, Says Moeed Yusuf," *Daily Times* (blog), July 4, 2021, https://dailytimes.com.pk/784788/indian-intelligence-agency-involved-in-johar-town-blast-says-moeed-yusuf/.

[13] Interactive Media Pakistan- imedia.com.pk, "Interactive Media - Digital Media On Demand Globally," accessed July 11, 2021, http://www.imedia.com.pk/.

[14] "Trading Corporation of Pakistan Private Limited - TCP," accessed July 11, 2021, https://tcp.gov.pk/.

accessed without any difficulty. One may find several applications on Google Play Store, can be downloaded easily to get such details at no cost. One such application is *"Pakistan Latest Sims Database 2021"* developed by some unknown *Mr. Soft and Company*. The responsibility for the leakage of such critical personal information directly lies on Mobile Operators and PTA. Therefore, there is a dire need to finalize the draft Personal Data Protection Bill and to ensure its enforceability.

A Comparison of Cybersecurity Infrastructure in Pakistan with Regional Countries

Compared to Pakistan, the cybersecurity infrastructure in China and India is well established and cyber incident response mechanism has been institutionalized. The following table depicts this difference[15].

	Pakistan	**India**	**China**
Legal Frameworks	• Electronic Transaction Ordinance (2002) • Investigation for Fair Trial Act (IFTA) (2013) • Pakistan Telecommunication Act (PTA) (1996) • Prevention of Electronic Crime Act (PECA) (2016) • Protection (Against Online Harms) Rules, 2020	• Information Technology Act (**IT Act**) 2000 *amended in 2008.*	• Cybersecurity Law • Counter-Terrorism Law • National Security Law
National Cyber Security Strategy Documents	• National Cyber Security Policy 2021 • Digital Pakistan Policy 2021 *(Under Review)*	• National Cyber Security Strategy *(Under Review)* • Land Warfare Doctrine (LWD) 2018 of Indian Army • Basic Doctrine of Indian Air Force • National Information Security Policy and Guidelines ***(Ministry of Home Affairs)*** • National Cyber Security Policy ***(Ministry of Electronics and IT)*** • Information Technology (Reasonable	• International Strategy of Cooperation in Cyberspace (**Ministry of Foreign Affairs**) • National Cybersecurity Strategy (**Cyberspace Administration of China CAC**) • China Military Strategy (**Ministry of National Defense**)

[15] "UNIDIR," accessed July 11, 2021, https://unidir.org/cpp/en/.

		Security Practices and Procedures and Sensitive Personal Data or Information) Rules	
Dedicated Authorities & Agencies	• Ministry of IT & Telecommunication **(MoITT)** • National Response Center for Cyber Crime (NR3C) working under **FIA** • National Center for Cyber Security *(NCCS)*	• National Cyber Security Coordination, **PM's Office** • JS Cyber Diplomacy, Cyber Diplomacy Division, **Ministry of External Affairs** • AS, National Emerging and Strategic Technologies *(NEST)* Division, **Ministry of External Affairs** • Ministry of Electronics and IT • National Security Council Secretariat • Cyber Swachhta Kendra *(National Center for Malware and Botnet Analysis)* • Cyber and Information Security (C&IS), **Ministry of Home Affairs** • National Technical Research Organization *(Responsible for Cyber Threat Intelligence and OSINT)* • National Critical Information Infrastructure Protection Centre (NCIIPC) • India Cyber Crime Coordination Center *(I4C)*	• Cyberspace Administration of China (CAC) • Cyber Security Association of China • Strategic Support Force (**PLA**) • Cyberspace Strategic Intelligence Research Center • Ministry of Industry and Information Technology
National CERTs (Computer Emergency Response Teams)	**N / A**	CERT - In	National-CERT of China
	Part of both UN Processes: Open-Ended Working Group (OEWG) and Group of Governmental Experts	**Part of both UN Processes:** Open-Ended Working Group (OEWG) and Group of Governmental Experts (GGE) on	**Part of both UN Processes:** Open-Ended Working Group (OEWG) and Group of Governmental Experts

Bilateral & Multilateral Cooperation	(GGE) on Developments in the fields of information and Communication Technologies in Context of International Security. • Part of OIC-CERT • SCO • ITU (International Telecommunication Union) **Bilateral Cooperation** Draft Agreement between Pakistan Russia on bilateral cooperation in the field of information security (*under review*).	Developments in the fields of information and Communication Technologies in Context of International Security. • SCO • ITU (International Telecommunication Union) **Bilateral Cooperation** • India-Japan Cyber Dialogue • India-Israel Cyber Security Dialogue • India-UK Cyber Security Dialogue • India-U.S. Homeland Security Dialogue • India-Australia Cyber Security Dialogue • India-ASEAN Cyber Security Dialogue • India-EU Cyber Dialogue • Russia-India Cyber Consultations • Joint Declaration of Intent on Germany-India Cooperation on Cyber Policy • India-Kenya Joint Working Group on Cyber Security • India-Qatar Cooperation on combating Cyber Crimes	(GGE) on Developments in the fields of information and Communication Technologies in Context of International Security. • SCO • ITU **Bilateral Cooperation** • China-Russia Cybersecurity Agreement (2015) • China-US Cybersecurity Agreement • Australia-China Cybersecurity Dialogue • China-Japan-Korea Annual Meeting for Cybersecurity Incident Response • China-Korea Cybersecurity Forum • China-UK High-Level Security Dialogue • China-US Cybersecurity Dialogue

An Appraisal of Draft National Cybersecurity Policy

The approval of the National Cybersecurity Policy is a step in the right direction[16]. This policy includes almost all the ingredients necessary to build-up a resilient cybersecurity infrastructure in Pakistan. It talks about establishing an institutional framework, creation of CERTs (national, sectoral, and organizational levels), and nSOC

[16] "Pakistan Government Approves New Cybersecurity Policy, Cybercrime Agency," The Daily Swig | Cybersecurity news and views, August 5, 2021, https://portswigger.net/daily-swig/pakistan-government-approves-new-cybersecurity-policy-cybercrime-agency.

(National Security Operation Center) to protect critical infrastructure, working on information security standards for the public and private sector, capacity building, R&D, foreign collaborations, etc. There is also a reference to Cyber Governance Policy Committee (CGPC); a policy formulation and oversight body, its core functions have also been stated. However, this policy leaves many questions unanswered.

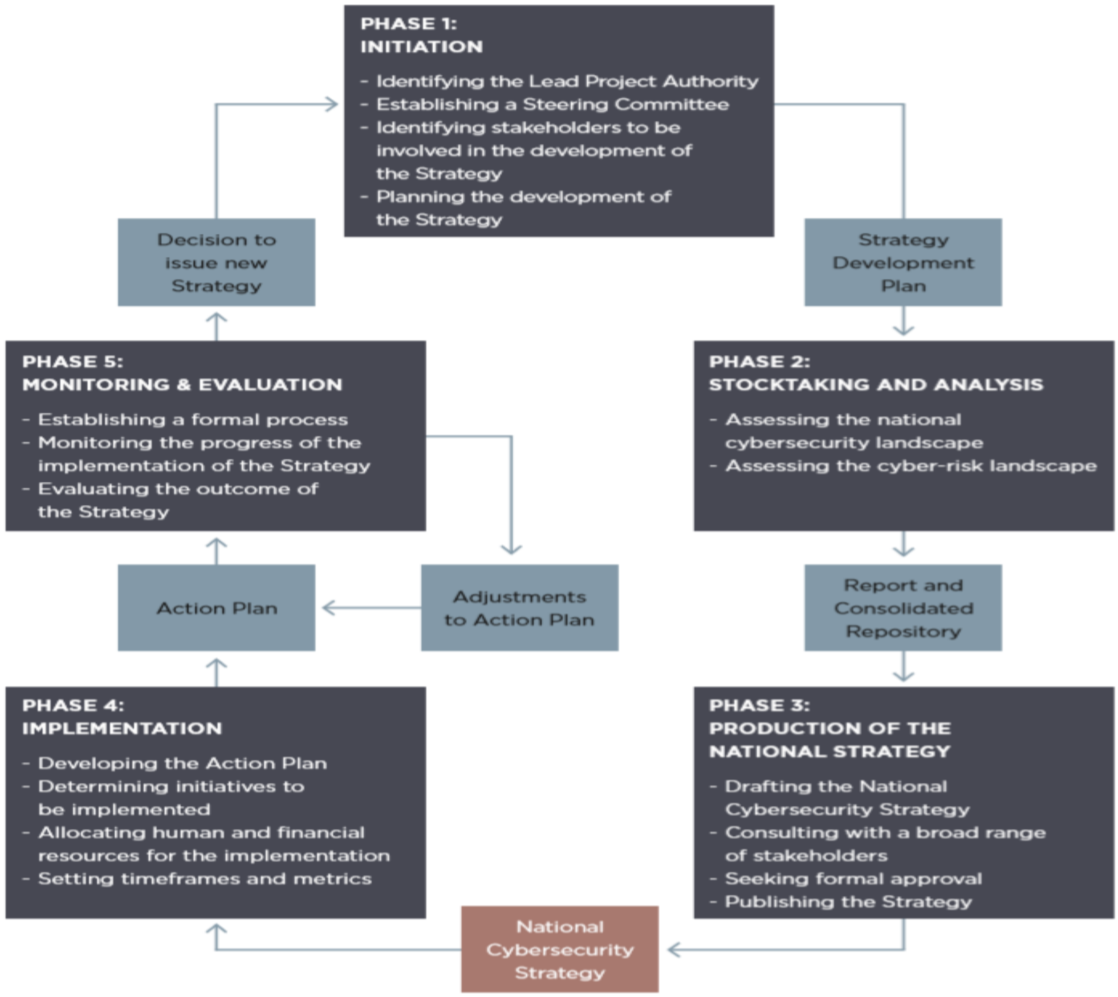
The approval of this policy is a step in the right direction and will help lay foundations of a resilient cybersecurity ecosystem in the country to counter the threats emanating from cyberspace. This policy will be instrumental in setting up the necessary institutions/agencies responsible to preempt, respond and neutralize any cyber-attack against the critical infrastructure of the country.

However, there are some points in the policy which need further clarifications. Such as, what would be the composition of the Cyber Governance Policy Committee? Will it work independently and who will be the chair of the committee? The draft policy also doesn't shed light on the details of the institutions which will be created to implement the policy. In short, the draft policy tells what is required to do, but doesn't answer how to do it and who will be responsible to put policy into action.

The government of Pakistan may get guidance from the document entitled *"Guide to Developing a National Cybersecurity Strategy",* published by the International Telecommunication Union (ITU)[17]. The guide contains the details complete lifecycle of a national cybersecurity strategy as depicted in the below diagram[18].

[17] "Guide to Developing a National Cybersecurity Strategy - Strategic Engagement in Cybersecurity," ITU, accessed July 13, 2021, https://www.itu.int:443/en/publications/ITU-D/Pages/publications.aspx.

[18] KKIENERM, "Cybercrime Module 8 Key Issues: National Cybersecurity Strategies - Lifecycles, Good Practices and Repositories," accessed July 13, 2021, //www.unodc.org.



Way forward Strategy for Pakistan

Synergizing the Efforts of Stakeholders

The analysis of cyber threats facing by Pakistan identifies the disjointed efforts of relevant agencies and stakeholders. They are working in silos instead of collaborating. To create synergy, the national mapping of these efforts is necessary.

Appointing National Cybersecurity Coordinator

Appointing National Cybersecurity Coordinator as a single point of contact will help streamline the efforts for developing the cybersecurity ecosystem in the country. He may be appointed as the chair of the Cyber Governance Policy Committee (CGPC). Newly formed National Cybersecurity Agency, National Cyber Threat Intelligence Agency, and CERTs will work under CGPC. The post of National Cybersecurity Coordinator may be created in Prime Minister's Office (PMO). Other stakeholders of the CGPC may include the Ministry of Finance, MoFA, MoI, MoLJ, ISI, FIA, PTA, MoST, MoITT, SPD, Provincial Governments, cybersecurity experts, academia, and members from civil society. CGPC will take decisions with the inputs of all stakeholders. to give direction to formulate a holistic cybersecurity policy.

National Cybersecurity Agency of Pakistan

The establishment of a central agency or National Cybersecurity Agency responsible for countering attacks on critical infrastructure (Energy, Transport, Banking, Space, Defense, and Health) has become indispensable. The role of this agency would be to assess the national cybersecurity landscape by using a risk-based approach. It will identify all such critical infrastructure, survey to determine the type of ICT platform (both software and hardware) in use, and issue guidelines, monitoring and alerting the concerned authorities about any cybersecurity vulnerabilities/breaches that could interrupt the functioning of the Federal Government.

Formation of CERTs

The formation of CERT (*Computer Emergency Response Team*) at the national and provincial level has also become crucial. The same role can't be delegated to NR3C, which is a prosecution agency against cybercrimes. Besides responding to a cyber-attack, CERTs will be responsible to maintain a database of publicly available cybersecurity vulnerabilities also known as CVE (Common Vulnerability Exposure). National CERT will work in close coordination with the CERTs of other countries to timely neutralize an imminent cyber-attack.

Cyber Threat Intelligence Agency

There is an essential requirement for an agency responsible for Cyber Threat Intelligence, Cyber Reconnaissance, and Open-Source Intelligence (OSINT). Cyber threat intelligence is an emerging field to gather intelligence in cyberspace. The core task of this agency will be to monitor Dark Web, Open Web, and social media to gather data about the activities of terrorists, hackers, and elements working against Pakistan. Another worrying aspect of unregulated use of social media platforms can be observed in the form of posting sensitive information like flight routes and uploading imagery of sensitive military installations, missile sites obtained through IMINT (Imagery Intelligence) using Google Maps and other tools and OSINT (Open-Source Intelligence). Such sensitive information when made available publicly could be utilized by terrorists and other non-state actors and could be detrimental to cybersecurity. There are several Twitter handles involved in disseminating such sensitive information. The role of the Cyber Threat Intelligence Agency would be to keep a check on such accounts and then to contact Twitter and other online platforms for their removal[19].

Revamping the role of NITB

NITB (National Information Technology Board), whose job is to provide Information Technology support to Federal Ministries and Divisions should be made responsible to design, host and manage all the websites of the federal government. The same setup may be made at the provincial level too. NITB will also be responsible for the management of the *.gov.pk* domain. As per policy, the official website must not be designed, hosted, and managed by any private entity. Besides this, NITB's duty should be to perform necessary penetration testing and vulnerability assessment of existing government websites and applications to investigate cybersecurity vulnerabilities.

[19] "Adverse Impact of IMINT and OSINT on Pak-India Cyber CBMs," *Centre for Strategic and Contemporary Research* (blog), May 19, 2020, https://cscr.pk/explore/themes/defense-security/adverse-impact-of-imint-and-osint-on-pak-india-cyber-cbms/.

NITB will make sure of the availability of tested and certified IT products as per global practices. It will also be responsible to mitigate supply-chain related risks and making sure that the hardware products being utilized don't have any backdoor and the software products don't contain any vulnerability.
To define mandatory standards for the protection, management, processing, and storage of data and cybersecurity best practices in Federal Ministries and Divisions, NITB may benefit from Standards (*ISO-27001*) defined by ISO (International Organization for Standardization) for information security[20].
NITB may be assigned the task of formulating National Information Security Guidelines for both the public and private sectors. The proposed guidelines will extensively cover the domain; inter alia, Network and Infrastructure Security, Data Security, Personal Security, Cloud Computing, Mobile and Bring Your Own Device (BYOD), Social Media, Threats and Vulnerability Management, Web Application Security, Incident Management & Business Continuity.

Establishment of Data Centers and Backup Sites

To ensure business continuity, a state-of-the-art central data center with backup sites may be established for the security of critical government data. All the critical data of Federal Ministries and Divisions will be stored in the servers located in the data center. This data center will also be hosting all the servers, inter alia, email servers, Web Servers, and VPN Servers, used by the Federal Ministries and Divisions to provide online services to the citizens of Pakistan. Data centers may be established under the supervision of NITB.
A position of Chief Information Security Officer[21] (CISO) may be created in every Ministry and Division who will be responsible for information and data security and information security audits along with the implementation of cybersecurity standards and policies at the organizational level.

Capacity Building and R&D

Considering the high frequency of cyber-attacks, the private sector's role in the fields of research and development (R&D) and capacity building has become more central. Owning to the financial and technical resources constraints, the Public sector alone can't protect the country against cyber threats. The establishment of the National Center for Cyber Security (NCCS) for R&D and capacity building is a step in the right direction. However, the same role may be expanded by setting up R&D labs across Pakistan at commercial and university levels. These R&D labs will work in the areas of Cyber forensics, Botnet analysis, malware and virus signatures analysis, malware reverse engineering, and developing open-source software (*OSS*) and products for information security. These labs will work in liaison with international R&D labs like Semantic Labs, Sophos Labs, etc.
To promote Cyber Hygiene in public sectors, special modules on cybersecurity may be designed for the under-training officers during CTP *(Common Training Program)* and STP

[20] "ISO - ISO/IEC 27001 — Information Security Management," ISO, accessed July 12, 2021, https://www.iso.org/isoiec-27001-information-security.html.
[21] Josh Fruhlinger, "What Is a CISO? Responsibilities and Requirements for This Vital Role," CSO Online, April 1, 2021, https://www.csoonline.com/article/3332026/what-is-a-ciso-responsibilities-and-requirements-for-this-vital-leadership-role.html.

(Specialized Training Program). Similarly, cybersecurity may be included as a compulsory subject at school and college levels for awareness.

Cryptocurrencies and FATF

Cryptocurrencies are gaining traction in Pakistan. However, till now there exists no regulatory framework in the country to regulate the transactions made in cryptocurrencies like Etherum, Bitcoin, etc. Despite the fact that the use of cryptocurrencies is illegal in Pakistan and the State Bank of Pakistan (SBP) has issued clear instructions in the regard.[22], there are reports that people are still finding ways to mine them[23]. Such situation is extremely alarming in the context of Pakistan's compliance with FATF's standards, as the absence of any regulatory framework or guidelines, AML/CFT/CPF Regulatory Authorities will be unable to implement the Know Your Customer (KYC), Anti-Money Laundering (AML), and TFS (Targeted Financial Sanctions) related controls[24].

SECP issued a position paper entitled *Regulations of Digital Assets Platform*[25]; moreover, the KP government also announced its plan to build pilot cryptocurrency mining farms in the province[26]. However, until now, there is no regulatory framework in Pakistan to control the trading in crypto-currencies.

As a first step, PTA may be advised to block access to all sites, digital wallets, and applications providing services for trading in cryptocurrencies.

Cybersecurity: As an essential element of Pakistan's Foreign Policy

Cyber-attacks are transnational, hence require multinational coordination to neutralize them. Considering the direct link of cybersecurity with national security, cyber-defense should become an integral part of Pakistan's foreign policy. We need to guarantee the presence of our diplomats and experts on all multilateral forums on cybersecurity such as UN OEWG and GGE on Developments in the field of information and Telecommunications in the Context of International Security, UN-OICT *(UN Office of Information and Communication Technologies)*, ITU-Impact *(International Multilateral Partnership against Cyber Threats)*, SCO, OIC, Asia-Pacific Security Incident Response Coordination Working Group (APSIRC-WG). We also need to collaborate with multilateral cyber defense forums like the ASEAN-Singapore Cybersecurity Center of Excellence and the NATO Cooperative Cyber Defense Center of Excellence (*CCODCOE*).

Pakistan must engage itself in bilateral cybersecurity dialogues with other countries for technical cooperation. We may start such dialogues with China, Russia, and Turkey as an agenda item in Bilateral Political Consultations on Arms Control, Disarmament, and Non-Proliferation.

September 2019 attack on KudanKulam nuclear power plant in India, attributed to a North Korean hacker group "Lazarus", was the first cyber-attack on a nuclear installation

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22 "State Bank of Pakistan," accessed July 11, 2021, https://www.sbp.org.pk/bprd/2018/C3.htm.

23 "Police Arrest Two Men for Mining Bitcoins in Shangla," The Express Tribune, January 25, 2020, http://tribune.com.pk/story/2144130/police-arrest-two-men-mining-bitcoins-shangla.

24 "NOW Is the Time for Pakistan to Regulate Bitcoin Investing - Business - DAWN.COM," accessed July 11, 2021, https://www.dawn.com/news/1624511.

25 "Position-Paper-Regulation-of-Digital-Asset-Trading-Platforms.Pdf," accessed July 11, 2021, https://www.secp.gov.pk/document/position-paper-regulation-of-digital-asset-trading-platforms/?wpdmdl=40643.

26 Reuters, "Govt Plans to Build Pilot Cryptocurrency Mining Farms in KP," DAWN.COM, March 19, 2021, https://www.dawn.com/news/1613320.

in South Asia[27]. There were reports that the same malware also targeted the Indian Space and Research Organization (ISRO)[28]. Moreover, the growing incidents of sporadic cyber skirmishes between India and Pakistan could be detrimental to regional peace and stability, especially when cyber-attacks lack the element of attribution. Such incidents call for the Cyber-CBMs between India and Pakistan. Both countries may sign an agreement on not conducting cyber-attack on nuclear installations. In this regard, Article 1 of the Agreement on the Prohibition of Attack against Nuclear Installation and Facilities[29] between India and Pakistan could be modified by making an explicit reference to "*Cyber-attacks*".

Pakistan should also play an active role in ongoing global efforts to define norms and behaviors for responsible behavior in cyberspace and defining code of conduct for cyberwarfare under IHL. This can only be done by sharpening the skills and expertise of Pakistani diplomats and make them capable to better present the case of Pakistan on different multilateral forums. Foundations may be laid right from the beginning in the Foreign Services Academy. A special module on Cybersecurity may be added. Special lectures and workshops may be arranged. The existing module on international law may be modified and the topics on emerging concepts of cyberwar under IHL and ongoing debates on norms building and responsible behavior in cyberspace may be included. The fellowships and training programs offered by UNIDIR, Belfer Center, Stimson Center, and VCDNP may be made available to get international exposure and skills development in the domain of cybersecurity.

[27] "An Indian Nuclear Power Plant Suffered a Cyberattack. Here's What You Need to Know. - The Washington Post," accessed July 12, 2021, https://www.washingtonpost.com/politics/2019/11/04/an-indian-nuclear-power-plant-suffered-cyberattack-heres-what-you-need-know/.

[28] "Snapshot," accessed July 11, 2021, https://www.firstpost.com/tech/news-analysis/isro-was-targeted-by-the-same-malware-that-was-used-to-attack-npcils-kudankulam-nuclear-plant-report-7608621.html.

[29] "PAB1232.Pdf," accessed July 12, 2021, https://mea.gov.in/Portal/LegalTreatiesDoc/PAB1232.pdf.

Perspectives of Product Lifecycle Management and SWOT Analysis for Science Diplomacy

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1-Introduction:

"**Diplomacy** refers to spoken or written speech acts by representatives of states (such as leaders and diplomats) intended to influence events in the international system (Trager 2016)".

Science diplomacy is the use of scientific collaborations among nations to discuss joint problems and to build beneficial international partnerships.

"In January 2010, the Royal Society and the American Association for the Advancement of Science (Society 2010) noted that, science diplomacy refers to three main types of activities:

- Science in diplomacy: Science can provide advice to inform and support foreign policy objectives.
- Diplomacy for science: Diplomacy can facilitate international scientific cooperation.
- Science for diplomacy: Scientific cooperation can improve international relations".

"In industry, **product lifecycle management** (PLM) is the process of managing the entire lifecycle of a product from its inception through the engineering, design, and manufacture, as well as the service and disposal of manufactured products (Kurkin and Januška 2010)." "PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise (Guide n.d.)."

"**SWOT analysis** (or SWOT matrix) is a strategic planning technique used to help a person or organization identify strengths, weaknesses, opportunities, and threats related to business competition or project planning (Mindtools n.d.)".

"This technique, which operates by 'peeling back layers of the company' (research n.d.) is designed for use in the preliminary stages of decision-making processes and can be used as a tool for evaluation of the strategic position of organizations of many kinds (for-profit enterprises, local and national governments, NGOs, etc.) (Caves 2004). It is intended to specify the objectives of the business venture or project and identify the internal and external factors that are favorable and unfavorable to achieving those objectives. Users of a SWOT analysis often ask and answer questions to generate meaningful information for each category to make the tool useful and identify their competitive advantage".

2-Perspectives of Product Lifecycle Management in Science diplomacy

"For simplicity the stages described are shown in a traditional sequential engineering workflow. The exact order of event and tasks will vary according to the product and industry in question, but the main processes are (Gould 2010)" shown in Table 1. The phases of Product life cycle offer gates to science diplomacy, as shown in Table 1.

Table-1: Perspectives of Product Lifecycle management in Science Diplomacy

Product lifecycle phases		**Gates of science diplomacy**
"Phase 1: Conceive"	"Imagine" "specify" "plan" "innovate"	• Scientific conferences and seminars. • Defense exhibitions. • Journal publications.
"Phase 2: Design"	"Describe" "define" "develop" "Test" "analyze" "validate"	• Joint Production Projects. • Joint R&D Projects. • Transfer of technology agreements.
"Phase 3: Realize"	"Manufacture" "Make" "build" "procure" "produce" "sell" "Deliver"	• Contracts. • Intergovernmental treaties. • Imports and exports agreements.
"Phase 4: Service"	"Use" "operate" "maintain" "support" "sustain" "phase-out" "retire" "recycle" "disposal"	• Technical support. • "Supply of spare parts." • Up gradation packages.

The Phases of Product lifecycle can help in science diplomacy. For example, scientific conferences and defense exhibitions may help to conceive new products; the science diplomacy may be used to visit Labs and Factories of other countries, resulting in joint production or R&D projects and transfer of technology agreements to help in Design phase of Product lifecycle management.

3-Perspectives of SWOT Analysis in Science diplomacy

A SWOT Analysis in Pakistani perspective is shown in Table-2.

Table-2: "SWOT Analysis"

	"Helpful *To achieving the objective"*	**"Harmful** *To achieving the objective"*
"Internal origin"	**STRENGTHS:** • Export items • Industrial infrastructure.	**WEAKNESSES**: • Lack of mineral resources • Lack of trained manpower

	• Cheap Hydropower resources	• Poor transportation resources
"External origin"	**OPPORTUNITIES**: • New markets and customers • New suppliers of raw materials • Offers of Joint R&D Projects	**THREATS:** • Threat of war in disputed areas • Threat of FATF sanctions • Threat of cross border terrorism

The SWOT Analysis in Table 2 can help in Science Diplomacy. For example, opportunities of new markets and customers may be exploited with science diplomacy with negotiations, and internal weakness such as poor transportation resources may be improved with joint projects with friendly countries.

4-Example of Science Diplomacy: "International Space Station":

"The International Space Station (ISS) is a modular space station (habitable artificial satellite) in low Earth orbit. It is a multinational collaborative project involving five participating space agencies: NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), and CSA (Canada) (Kitmacher 2006)". "The ownership and use of the space station is established by intergovernmental treaties and agreements (ESA 2021). The station serves as a microgravity and space environment research laboratory in which scientific research is conducted in astrobiology, astronomy, meteorology, physics, and other fields (NASA, Fields of Research 2021). The ISS is suited for testing the spacecraft systems and equipment required for possible future long-duration missions to the Moon and Mars (NASA, ISS research project 2021)".

"Involving five space programs and fifteen countries (NASA, International Cooperation 2021), the International Space Station is the most politically and legally complex space exploration programme in history (NASA, International Cooperation 2021). The 1998 Space Station Intergovernmental Agreement sets forth the primary framework for international cooperation among the parties. A series of subsequent agreements govern other aspects of the station, ranging from jurisdictional issues to a code of conduct among visiting astronauts (Farand 2000)."

"Participating countries of International space station are; Canada, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, Japan, Russia and United States".

The success example of International Space Station shows that huge projects may be operated over a period of several years with science diplomacy, which would otherwise be very difficult for one country to operate. "The research literature has details (Payette 2012) on lessons from the International Space Station for Science Diplomacy".

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Dispatches from the Field

Academic Networking—a critical step in sustaining scientific research in Pakistan

(Dr. Muhammad Zaheer, Assistant Professor, Syed Babar Ali School of Science and Engineering, LUMS)

After joining LUMS back in 2014, the first and rather challenging task was to train passionate undergraduate and graduate students. But before that, I needed the supplies, consumables, and analytical tools required for my research that centers on designing robust catalysts for renewable energy, green chemicals, and environmental remediation. Thankfully, LUMS provides a startup research grant to newly hired faculty at the rank of assistant professor, which significantly helps build a research group's foundation. I was lucky to win a competitive research grant under National Research Program for Universities (NRPU) from the Higher Education Commission Pakistan (HEC) in 2015, which immensely helped us procure the equipment needed for our research. However, some additional analytical tools were still required to conduct quality research that could be communicated with the international scientific community. Building international collaborations across Europe, China, the USA, and the UK has proved highly effective in sustaining our research

The first research collaboration I started was with my PhD research adviser, Professor Rhett Kempe, in Bayreuth, Germany. Both institutes signed a memorandum of understanding to cooperate on research and exchange students and research staff. As a gesture of kindness, the University of Bayreuth also gifted a gas chromatograph (GC) equipped with Flame Ionization Detector (FID), which significantly helps our group identify and quantify biomass valorization products—an area our research group focusses on. Professor Kempe also supported my short-term stays in Bayreuth, during which I supervised some master students in their research projects. Our mutual collaboration resulted in four research articles in reputed scientific journals.

In 2015, I applied for Phase 6 of the research grant under the Pakistan-US Science and Technology Cooperation program. Professor George Huber—one of the leading scientists in biomass conversion, kindly agreed to work as a co-principle investigator. Unfortunately, our project was not funded, but we received an encouraging review of our grant proposal. We again applied for phase 7, but the outcome was the same. However, these experiences brought the two research collaborators together. Our recent project with Professor Huber as the short-term consultant has been approved for funding under National Research Program for Universities (NPU) funded by the Higher Education Commission of Pakistan (HEC). Professor Huber also gave a very interesting research talk on the valorization of polymeric materials into fuels, chemicals and materials to our students on September 30, 2021.

In 2018, I was awarded a Charles Wallace Fellowship to visit the University of Cambridge in the UK. The grant's objectives were to start new collaborations with scientists in the UK. In the Center of Atmospheric Sciences at the Department of Chemistry, Professor Rod Jones kindly agreed to host my visit. During my stay, I gave a talk at the Department of Chemistry and attended the weekly group meetings of Professor Jones' research group. Moreover, I learned new data analysis skills and the development of low-cost sensors for ambient air quality monitoring.

My visit to Cambridge was very productive and led to a new research division in our group. Due to pressing atmospheric pollution, we decided to probe the chemical composition of particulate air pollution to find their potential sources. We wrote two research grants with Professor Rod on mitigating Lahore smog by developing a hyperlocal network of low-cost air monitors. We proposed the establishment of a reference air monitoring station at LUMS and a network to validate the data collected from low-cost sensors mounted in the city. We submitted grants under Innovative and Collaborative Research Grant (ICRG)—jointly funded by the HEC and the British Council. Our grant application was successful in the initial phase but got rejected in the final round. We submitted the same grant to the HEC's Grand Challenge Fund (GCF) with the same team. However, the project couldn't make its place on the list of awardees.

In 2019, one of my friends from Bayreuth—then a postdoctoral fellow in the UK—contacted me asking if I am interested in applying for a grant on biomass conversion. His supervisor for looking for a potential research partner in Pakistan to apply for a research grant under Tackling Global Development Challenges through Physical Sciences Research funded by the Grand Challenge Research Fund. I agreed happily, and it was the advent of collaboration with Professor Jianliang Xiao from the University of Liverpool. Since then, we have written grants under various grant calls such as ICRG-HEC.

I have attended the annual meetings of the American Chemical Society in 2018 and 2019 to present our research. During these meetings, I worked with several American scientists and researchers who share similar research interests. Professor Kevin kittilstved, who attended one of my talks, took a great interest in our research, and we agreed to collaborate on areas of mutual interest.

Before the global pandemic hit the world, one of my PhD students visited the University of Nottingham under the International Research Support Initiative Program (IRSIP). Professor Andrea Laybourn had shown great interest in the microwave synthesis of metal-organic framework—highly crystalline nanoporous materials. This is how we started our research collaboration which is still active. We have published one research article, and the other is ready to be submitted for publication. Professor Laybourn helps us get our materials characterized by methods such as X-ray Photoelectron Spectroscopy (XPS) and Transmission Electron Microscopy (TEM).

Over the past seven years, our research group has trained three PhD, fifteen MS, and ten BS students who are now pursuing higher education in the US or serving national institutes. Moreover, we have produced over sixteen research articles in reputed scientific journals. One of our research articles was the most downloaded research paper of the journal and was published as a "hot paper."

Our international collaborators have played a significant role in the success of our research group. In my case, various grant calls, travel grants, and participation in international conferences opened new doors of collaboration for our research group. Such cooperation provides us with the tools that are not available in Pakistan and play a pivotal role in whatever little research progress we make at LUMS.

The Reluctant Science Diplomat

Alaa Mazhar Bokhari (Career Diplomat, Ministry of Foreign Affairs, Pakistan)

There is something to be said about being thrown into the deep end without a life raft. More so if you didn't even know how to swim. That is how I felt walking through the maze-like corridors of the Food and Agriculture Organization in Rome seven years ago. As Pakistan's alternate permanent representative to the Rome based UN food organization, I was expected to fill the big shoes that essentially a trained expert from Pakistan's Ministry of National Food Security and Research was supposed to fill. But budget cuts and a merry-go-round of political infighting has left the crucial seat of an Agricultural Counsellor in our Embassy in Rome empty for several years now. As always is the case in such situations, it is the officers from the Ministry of Foreign Affairs that are expected to pick up the slack. And we are all too happy to oblige; provided we get thrown a lifeline from time to time.

Unfortunately, that was not the case for me. I had to face it; despite my overzealous patriotism to be the best third secretary (beginner level diplomat) anyone had ever seen, I was in over my head. I learnt very quickly that those alien sounding jargons were specific terminologies that had specific meaning and scientific purpose. I could not afford to ignore those terminologies as they formed the basis of every document, report or resolution that was being tabled.

The obvious step was to reach out to the experts back in Islamabad; to get some important briefing material, atleast for the main events if not for the routine meetings. One such event was Pakistan co-chairing the International Year of Pulses 2016 along with Turkey. Though a lot of the heavy lifting had been done prior to my taking over as co-chair, there was still the matter of concluding the International Year on a high note. Burkina Faso proposed to have the event in their capital. A generous offer, however, one that was only taken up by the Pulses Secretariat and not the other country members, as they were unable to travel to the region.

Consequently, Pakistan, in collaboration with Turkey, offered to host a closing ceremony at our Embassy; where we presented all main dishes and desserts from our two countries, entirely made from pulses. The idea was a hit! Our technical presentations and an invigorating panel discussion resulted in an overall enthused audience, many of whom had joined globally through FAO's online platforms. Questions came in from farmers and growers with questions regarding their produce, from young students trying to learn about the impacts of climate change on agriculture and from activists trying to learn more about sustainability and how they could join hands with national governments to spread greater awareness regarding cultivation of pulses and their role in mitigating the impact of climate change.

As an innovative step further, a cookbook was also published (hardcopy and online) with all the delicious recipes from around the world using pulses. I personally wrote the recipes for the dishes we had served at the Embassy on that fateful event for the digital platform and had received a lot of positive feedback. It was then that I realized the impact of combining public diplomacy with science, to breakdown the bigger more complex concepts for the greatest outreach. FAO had offered the best platform for scientists and technical experts to come together and share their research and discoveries; however, it was when we the country representatives were able to interact with those experts and relay the research to our governments and vice versa, that the fruits of science diplomacy were actually harvested.

These interactions, I learnt, were the basis of science diplomacy. In my research, I discovered that there were many definitions of science diplomacy and despite the fact that the notion has been dated as far back as the Mesopotamian era, the actual coinage of the term has been quite recent. Regardless of which definition or era one subscribes to, there is no doubt that this interaction of science with international relations is not only essential but also unavoidable. With the lightening rate of technological advancements faced by society today and as most transactions, physical or cyber, transcend borders, diplomats have to come into play and they must have a rudimentary understanding of the subject in order to safeguard if not promote their national interests.

This is particularly important for the developing world. The Global Divide remains deep in terms of tech transfer, and it is only through active diplomacy that that divide can ever be bridged or at least be crossed over. Science Diplomacy has also become one of the fundamentals of a state's soft power. In my opinion it is a type of CBM (confidence building measure) especially between competitive or even acrimonious states, as scientific cooperation and exchanges provide that first signal of stability and progress. Lastly, science diplomacy has become a matter of global human survival. As the world has awakened to the requirement of international cooperation in dealing with the perils of food insecurity, climate change, water scarcity, nuclear arms race, cyber threats and possible militarization of outer space, so has the world realized that science diplomacy has been scattered across the diplomatic stage in these various forms and requires focused attention and resources.

That focus comes from regular updates and training courses. Most diplomatic services around the world have mandatory trainings/courses throughout the career of an envoy. A specialized module on science diplomacy within that course would not be redundant, with particular attention to matters of international /UN concern. Additionally, diplomats should be encouraged to attend international meetings and conferences on pressing contemporary topics. The exposure and exchange of ideas amongst peers leads to a quicker grasp of concepts and notions.

The bond between science and diplomacy thus is ever strengthening…inadvertently. But for better and tailored results, nations and their institutions must equip and train their representatives with relevant and current information, practical skills and constant backend support.

Science Diplomacy- Role of International Center for Chemical and Biological Sciences, University of Karachi, Pakistan -An Example of Sustainable Cooperation across the Globe

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BACKGROUND:

Science has no boundaries and thus its benefits must reach to all. Science and technology cooperation is the best way to promote rationality, appreciation, understanding, and collaboration between the nations, and to meet global challenges. International Center for Chemical and Biological Sciences (ICCBS), (HEJ Research Institute of Chemistry, and Dr. Panjwani Center for Molecular Medicine and Drug Research) (www.iccs.edu), University of Karachi, Pakistan, provides an excellent example of international collaboration in academic and research fields spread over last five decades, where the concept of science diplomacy for common good is practically implemented.

The ICCBS has established strong cooperation with various institutions in over 80 countries of the world. This cooperation includes training of young scholars for their graduate and post-graduate research studies, establishment of centers of excellence in various disciplines joint organization of capacity building events, and to conduct joint research projects. Since 1966, thousands of young scholars from six continents of the world have visited the ICCBS and received training, supervision, access to research facilities, research consumables During the training visits, ICCBS provides supervision, bench fee, access to research facilities, research consumables, local hospitality and mentorship of some of the prominent scientists.

Hundreds of joint research papers have been published with various collaborators in international peer reviewed journals. Faculty members from participating institutions been actively engaged in the capacity building programs, such as workshops, seminars, conferences, etc.

The ICCBS have several joint fellowship programs to support scholars from developing countries. Some of them are listed below;

1. Joint NAM S&T Centre-ICCBS Karachi (Pakistan) Fellowship (www.namstct.org)
2. TWAS Fellowship Program (https://twas.org/opportunity/twas-iccbs-postdoctoral-fellowship-programme)
3. COMSTECH Visiting Scientists Program (https://www.comstech.org)

BRIEF ABOUT The ICCBS, UNIVERSITY OF KARACHI, PAKISTAN

The International Center for Chemical and Biological Sciences (H. E. J. Research Institute of Chemistry, and Dr. Panjwani Center for Molecular Medicine and Drug Research), University of Karachi (www.iccs.edu) is one of the finest academic research establishments of chemical, biological and biomedical sciences in the developing world. This center has won more international awards than any other institution in Pakistan. These international awards include Mustafa (PBUH) Prize, Islamic Development Bank Prize for the Best Science Institution (twice 2004 and 2010), World Health Organization Collaborating Center, UNESCO Science Prize, Fellowship of the Royal Society (02), Khwarizmi International Prize, ECO and COMSTECH awards, while the national awards include Nishan-e-Imtiaz (01), Hilal-e-Imtiaz (05), Sitara-e-Imtiaz (13), Tamgha-i-Imtiaz (13), etc. ICCBS is internationally recognized by the UNESCO, OIC, and TWAS as their Center of Excellence.

Its reputation for scientific research and training extends far beyond the country's borders. Many institutions in ICCBS system have emerged from generous support of private sector, international grants, and sustained by the governments grants. In the last 5 decades, the ICCBS has earned major recognition as a focal center for thousands of young researchers from home and abroad in frontiers areas of science and technology.

SCIENCE DIPLOMACY: BUILDING CAPACITY OF SCIENCE

Science diplomacy is widely recognized as among the best practices for bringing nations together despite ideological and political differences. This has helped nations to address and solve regional and global problems and challenges.

Scientists are often referred as natural diplomats by the virtue of their scientific networking, collaborations, and educations are their main activities and strengths. Science has one language which is being understood and used by the similar communities beyond boundaries and borders. Scientists and scholars travel far and wide in order to teach, explore and learn scientific phenomenon. Consortium of scientists work closely to find solution of a common global challenge. Pandemic of COVID-19 is the biggest example where we saw the science diplomacy in its full action. COVID-19 is the biggest crisis faced by humanity of current age. This has affected virtually every individual on the face of the earth at the same time. The pandemic has shown that science is a global public entity which can save the humanity from suffering existential threats. Scientists across the world have worked together in order to identify, analyze, cure and mitigate the SARS-COV-2 infection. But the same time international science-policy interface structures and institutions are inadequate to address the challenges facing human and planetary health. The pandemic has exacerbated profound geopolitical shifts, created new tensions, and catapulted science and health diplomacy to the front pages.

SCIENCE DIPLOMACY IN ACTION: HIGHLIGHTS OF OUR WORK:

At the ICCBS, University of Karachi, we are deeply and committed to play our role in uplifting better image of Pakistan through our academic and scientific excellence. The ICCBS has signed 139 Memorandum of Understandings with various Universities and institutions across the globe. Under the auspices of these MoUs several research and academic activities have been conducted. These activities include exchange of faculty members and resources, training and joint supervision of young scholars, organization of joint

workshops, conferences and course, and etc. Below is the summary of some of our efforts to connect Pakistan to various regions of the world through science diplomacy.

ICCBS PAKISTAN- CHINA COOPERATION

The journey of collaboration between the International Center for Chemical and Biological Sciences (ICCBS), University of Karachi, and Chinese academic and research institutions is as old as the institution itself. Prof. Dr. Atta-ur-Rahman FRS, the then co-Director of the HEJ Research Institute of Chemistry, University of Karachi used to travel to Shanghai and meet with senior professors there in the 1970s. He initiated collaborative projects with them in the 1980s. Government of Pakistan and the Government of China jointly funded a research project in 1986 with Prof. Peng from the Shanghai Institute of Materia Medica, Chinese Academy of Sciences and ICCBS.

Since 1983, ICCBS is organizing international conferences on natural product chemistry, and at every conference welcomed a large delegations of Chinese scientists from several prestigious institutions of China.

Back in 2004, Sino-Pakistan Workshop on Pharmacology Standardization of Herbal Medicine was Organized by MOST of China, NATCM of China and MOST of Pakistan at National Level, a joint delegation from two institutions, the Institute of Medicinal Plant Development (IMPLAD), and the Institute of Chinese Materia Medica (ICMM), including the directors and senior scientists from those two institutions, such as Prof. Dr. Liu Xinmin, and Prof. Dr. Chen Shilin, visited ICCBS. This was followed by many joint activities.

The ICCBS has an active cooperation with Hunan University of Chinese Medicine (Changsha), Affiliated T.C.M. Hospital of Southwest Medical University (Luzhou), Xinjiang Traditional Uygur Medicine (Urumqi), Sino-bioway Group ltd. (Beijing), and many others. Some of ICCBS faculty members have been trained at the Animal Research Center of Hunan Province in Changsha, and Institute of Laboratory Animal Sciences (ILAS), Chinese Academy of Medical Sciences (CAMS).

Chinese-Pakistan cooperation mirror centers on TCM have been also been established recently at the ICCBS, University of Karachi, Pakistan and at Hunan University of Medicine in Huaihua, Hunan Province, by National Administration of Traditional Chinese Medicine (NATCM), and the Minister of health (Sindh).

A center named "Academician Professor Atta-ur-Rahman One Belt and One Road Traditional Medicine Research Center" was established in Hunan University of Chinese Medicine (HUCM). The laughing ceremony of the center was attended by the Pakistan Minister of Science and Technology (Oct. 2019). ICCBS also carried out clinical trial of TCM for Hunan Anbang Pharmaceutical Co., Ltd.

ICCBS has an active MoU with Tianjin Institute of Industrial Biotechnology (TIB), Chinese Academy of Sciences (CAAS), and a delegation of scientists from Pakistan has visited Tianjin in 2017. A joint project has also been approved by the Chinese government. Few faculty members and scholars from ICCBS has also been trained at TIB in the field of industrial biotechnology.

Prof. Chen Zhenfeng from Guangxi Normal University (GNU). He came for a conference in 2013, then he also invited delegation form the ICCBS to attend their conference. Through these informal interactions, we exchanged scholars, more from Pakistan. There are several funded projects. They appointed Prof. Dr. M. Iqbal Choudhary as an advisor to the national key laboratory at GNU. A joint Laboratory for Chemistry and Molecular Engineering of Medicinal Resources was established in Guilin.

ICCBS have important contact with the China National Rice Research Institute, Chinese Academy of Agricultural Sciences, Hangzhou, China. The field trial of Chinese rice varieties is on the way locally. A "Sino-Pakistan Hybrid Rice Research Center" have been established at the ICCBS.

There are many other collaborations of ICCBS with Chinese Universities, just to name some of them; such as Beijing Genomics Institute (BGI), Wuhan Institute of Virology, Xinjiang Technical Institute of Physics and Chemistry, Shenzhen Institutes of Advanced Technology, Institute of Food Science and Technology, etc. With the BGI, ICCBS has developed a vigorous collaboration that involved training of staff members in advanced genomics. As a result, Jamil-ur-Rahman Center for Genome Research was established. Independently, ICCBS have developed the collaboration with SinoPharm and conducted a Phase I clinical trial on their COVID-19 vaccine.

Prof. Atta-ur-Rahman FRS, became a fellow of the Chinese Academy of Sciences and won the China International Science and Technology Cooperation Award. Prof. Dr. M. Iqbal Choudhary, Director ICCBS, received the "Distinguished Scientist" Award from the Chinese Academy of Sciences and the "Guangxi Silkball Friendship Award" from the Guangxi government.

A CASE STUDY OF COOPERATION BETWEEN ICCBS, PAKISTAN AND UNIVERSITY OF TUBINGEN, GERMANY

The ICCBS has a long history of science diplomacy with German Institutions. Our founding Father late Prof. Dr. Salimuzzaman Siddiqui FRS, has obtained his Ph. D. degree from Germany, and remain connected with German institutions throughout his life. The best example of sustainable cooperation between two institutions is the cooperation between ICCBS and University of Tubingen. This all started with the visit of young Prof. Dr. Wolfgang Voelter from University of Tubingen in 1970s. This historic visit resulted as the most fruitful and sustained collaboration. Since his first visit to Pakistan till his sad demise in 2000, he remains committed to help Pakistani scientists and science institutions, particularly ICCBS in the most profound manner. He convinced German Government and GTZ to approve an initial allocation of 2.3 million DM, followed by another allocation of 3.5 million DM to support the establishment of H. E. J. Research Institute of Chemistry (HEJRIC), ICCBS, University of Karachi. Prof. Voelter has trained and supported a large number of young Pakistani scientists in their careers as a true mentor. Approximately 40 Pakistani scientists, students, and technicians were given advanced research training in the esteemed laboratory of Prof. Wolfgang Voelter, including 20 full time doctoral students.

Over 90 German students from University of Tubingen have also visited the HEJRIC to carry out part of their Diploma work. Over 150 research publications in best peer reviewed journals have been published in collaboration with German scientists.

Prof. Voelter has received several international awards, including prestigious civil awards, Hilal-e-Pakistan, and Sitara-e-Pakistan, from the President of Pakistan. He has an unparalleled love, affection, and respect for the people of Pakistan, and confidence on their talent and abilities. He was truly the ambassador of Pak-German Scientific cooperation, and friendship between the two great nations.

The ICCBS has a large research complex named as *Prof. Wolfgang Voelter Laboratories Complex,* constructed in recognition of unparallel services of Prof. Wolfgang Voelter (Tübingen University, Germany) in the establishment of the ICCBS. This magnificent building was inaugurated in 2016 at the auspices occasion of 85th Birthday of Prof. Voelter. Ambassador of Germany in Pakistan, Her Excellency Ina Lepel, inaugurated the large building.

National Institute of Virology was established in 2018 with the vision to improve the health status in Pakistan, despite the fact that Pakistan has the second highest global burden of viral diseases, the country lacks in the national capacity in the field of virology. The institute was inaugurated in September 2019. The center has procured state-of-the-art technologies including Bio Safety Level-3. This center has conducted over 0.35 million PCR based test for the diagnosis of COVID-19. This center provides the excellence in research, to conduct scientific investigation on viral and other diseases. A very prominent virologist Prof. Dr. Thomas Iftner from University of Tubingen is helping ICCBS for the training of faculty and staff in field of virology. In addition to this ICCBS has linkages with Mediagnost Reutlingen, the University of Hamburg, and Ruhr-University Bochum, Germany. A part from these, the ICCBS have active collaboration with University of Hamberg, Max Delbrück Center, Berlin, and Max Plank institute in Germany.

ICCBS CONNECTING PAKISTAN WITH WESTERN COUNTRIES

Large number of faculty members of the ICCBS have been formally trained in the various Universities of the United States of America, these include Pennsylvania State University, Cornell university, Scripps Institute, University of Illinois at Chicago, University of Kansas, University of Mississippi, Rockefeller University and many other top universities of USA. Many Professors from these Universities have visited ICCBS several times. US-Pak Binational workshops on Natural Products Chemistry during 1985-2000 have played an important role in research collaboration. More than 150 Joint Research Publications with various Scientists of United States of America have been published. The graduates of ICCBS are now serving as faculty members in various universities and institutions of USA. They are permanent ambassadors of ICCBS and Pakistan, and helping in brining brighter side of Pakistan to the Western world.

In addition, ICCBS has linkages with Argentina, Austria, Brazil, Belgium, Bulgaria, Canada, Chile, Colombia, Croatia, Cuba, Czech Republic, Denmark, France, Greece, Hungary, Ireland, Italy, Mexico, Netherlands, Norway, Poland, Scotland, Serbia, Spain, Sweden, Switzerland and United Kingdom. Several tens of research publications have been published with the scientists from these countries. Table-1 represents numbers of joint research publications, MoU(s) and scholars from given countries.

Table-1: Statistics of Cooperation of ICCBS with Countries of West

Name of Country	Joint Research Publications with Scientists	Academic collaboration (MoU)	Scholars/ Visiting Scientists Visited ICCBS
Argentina	1	-	-
Austria	15	1	10
Brazil	2	-	-
Belgium	7	-	10
Bulgaria	1	-	-
Canada	31	2	2
Chile	2	-	1
Colombia	-	-	1
Croatia	-	-	1
Cuba	-	-	1
Czech Republic	2	-	1
Denmark	2	-	-
France	12	8	4
Germany	70	4	120
Greece	25	-	25
Hungary	1	-	10
Ireland	1	-	-
Italy	10	3	-
Mexico	1	-	-
Netherlands	2	-	-
Norway	1	-	-
Poland	1	-	-
Scotland	1	-	1
Serbia	1	-	-
Spain	7	-	-
Sweden	6	-	5

Switzerland	7	-	10
United Kingdom	24	-	30
United States of America	77	8	50

SCIENCE DIPLOMACY WITH SOUTH ASIAN ASSOCIATION FOR REGIONAL COOPERATION (SAARC) AND OTHER ASIAN COUNTRIES

Even in the politically difficult times ICCBS remain connected with Indian scientists. They have been visiting Pakistan to attend international conferences being organized by the ICCBS. In this way we have played our humble role to ease out the diplomatic relations between two neighboring countries. Several peer reviewed publications have resulted based on this cooperation. ICCBS has signed and memorandum with Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre). New Delhi, India, to support the visiting scientists and scholars visiting ICCBS, Pakistan.

Several students from Bangladesh have visited ICCBS and completed their doctoral and post-doctoral studies. Exchange of faculty members and students from both side is a regular practice. ICCBS has hired few full time permanent faculty members from Bangladesh as rules of HEC, Pakistan. These collaborations have resulted in many high quality publications.

There are more than 50 alumni of the ICCBS only in Sri Lanka who have been trained at the ICCBS. This has resulted in large number of publications academic cooperation especially with General Sir John Kotelawala Defense University, Ratmalana, and Industrial Technology Institute (ITI), Sri Lanka.

Similarly, several students from Nepal have completed their Ph.D. from the ICCBS and now serving as faculty members in Nepal and helping towards uplifting the country's economy.
Table-2 represents numbers of joint research publications, MoU(s) and scholars from given countries.

Table-2: Statistics of Cooperation of ICCBS with Asian Countries

Name of Country	Joint Research Publications with Scientists	Academic collaboration (MoU)	Scholars/ Visiting Scientists Visited ICCBS
Bangladesh	19	2	30
China	22	54	150
India	7	1	25
Indonesia	14	4	25
Iran	22	6	50
Japan	13	1	10
Korea	3	-	10
Malaysia	78	8	100
Mongolia	6	-	1
Myanmar	2	-	6
Nepal	19	-	9
Philippines	5	-	3
Singapore	1	-	-
Sri Lanka	35	3	50
Taiwan	1	-	-
Thailand	7	1	2
Vietnam	-	-	1
Kazakhstan	6	7	30
Kyrgyzstan	1	-	-
Tajikistan	-	1	-
Uzbekistan	7	-	-

FLAGSHIP PROGRAMS FOR WOMEN SCIENTISTS FROM AFRICAN AND SUB-SAHARAN AFRICAN COUNTRIES

Despite of equal or sometimes higher proportions of female than male undergraduate students in science, female scientists are underrepresented at higher career stages. Globally women in science gets less number of opportunities to advance their skill and educations, they earn less money, they are less likely to get research grants, are less likely to be promoted, and hence are more likely to leave science than equally qualified men.

In order to specifically address lack of training options for women scientists and to strengthen their skills in science, ICCBS offer special flagship program for the graduate and post-graduate research and training. Over 30 female scholars visit ICCBS annually from African and sub-Saharan African Countries.Table-3 represents numbers of joint research publications, MoU(s) and scholars from given countries.

Table-3: Statistics of Cooperation of ICCBS with African Countries

Name of Country	Joint Research Publications with Scientists	Academic collaboration (MoU)	Scholars/ Visiting Scientists Visited ICCBS
Algeria	-	-	1
Cameroon	49	-	100
Congo	-	-	2
Egypt	40	1	20
Ethiopia	1	-	4
Gabon	1	-	2
Ghana	1	-	-
Liberia	1	-	-
Mauritius	2	1	2
Morocco	10	-	1
Nigeria	23	5	150
South Africa	7	-	-
Sudan	14	6	50
Tanzania	-	-	2
Uganda	-	1	1
Barkina Faso	-	-	1

ESTABLISHMENT OF CENTERS OF EXCELLENCE

Director ICCBS (author) is a renowned scientist of Pakistan and has made seminal contributions in the establishment of research centers, in various countries of the world. He has worked closely with many young scientists of developing countries, and helped them to initiate and sustain research despite constrained environment. A large number of these young scholars have received Ph. Ds based on their research which they have conducted in his supervision, and now supervising their own research groups successfully.

1. Dr. Choudhary has established and strengthened institutions, research centers, and laboratories in various developing countries, including a research center in Nigeria named after Prof. Dr. M. Iqbal Choudhary, "Iqbal Choudhary Centre for Natural Product Research" at Benin, Nigeria, established in December 2018.
2. A "Natural Product and Pharmacognosy Laboratory" at the Faculty of Pharmacy, Gazi University, Ankara was also established. "Natural Product Chemistry Center" at the Department of Chemistry, University of Younde I, Younde, Cameroon was developed.
3. Medicinal Plants Research Institute (MAPRI)" at the National Research Center, Khartoum, Sudan, was established and successfully running.

4. “Rahman Institute of Natural Products Development (RIND)” at the National Research Center, University Technology Mara (UiTM), Puncak Alam, Malaysia was established after the name of Prof. Dr. Atta-ur-Rahman FRS.
5. A “Laboratory for Research on Anti-Diabetic Plants” at the Department of Chemistry, Dhaka, Bangladesh was developed along with scientists from Bangladesh.
6. “Medicinal Plants Research Institute” at the Faculty of Chemical Sciences, Al-Farabi National Kazakh University, Almaty, Kazakhstan was established. Frequent visits from ICCBS faculty members are being conducted in order to train young Kazakh scholars.
7. “Center for Advanced Research” at the Basic Science Faculty, Sir General Kotelawala Defense University, Colombo, Sri Lanka was developed.
8. A “Laboratory for Bioorganic Chemistry” at the Department of Biochemistry, King Abdulaziz University, Jeddah, Saudi Arabia was established.

Representation of Pakistan in various International Conferences

ICCBS organize every major International Conferences, Symposia, and workshops regularly including IUPAC Symposium, EURASIA Conference, IBRO School, ASOMPS, OIC meetings, ANRAP, FACS, and IUCr conference. In addition to these faculty members from ICCBS are frequently been invited in top international conferences as invited speaker. This highlight the presence of Pakistani Science in front of the world. Faculty members have also been selected to attend the top international courses such as courses offered by Bruker, SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East), Agilent and etc.

Suggestions on Enhancing Science and Technology Co-operation Between Pakistan and other countries

Science and technology co-operation between countries are based on informal contacts, understanding, similar research interest and between cooperation between scientists. Therefore, providing opportunities for participation in international cooperation supporting visits of foreign scientists to relevant institutions, and student exchange are effective mechanism for fostering research collaboration, and nurturing institutional linkages. Support for reach projects with the involvement of foreign scientists is also help in developing Science and technology co-operation.

One innovative approach for developing sustainable Science and technology co-operation between Pakistan and other countries is to engage foreign experts in the supervision of M. Phil. and Ph. D.

Impact of ICCBS Science Diplomacy Initiatives

The ICCBS's scientific cooperation, spread over 5 decades, has had a profound impact on S & T landscape of south-south cooperation. There is hardly any country in the world where ICCBS graduates and guest scientists are not working. The ICCBS is indeed a household name in academic world, and truly regarded as the recognition of Pakistan in the world of science.

Science for Humanity

Lahore Science Mela 2019

Dr. Muhammad Sabieh Anwar and Charisma Wafee

Khwarizmi Science Society

Science shows peppered the Lahore Science Mela 2019.

Khwarizmi Science Society (KSS), founded by Dr. Saadat Anwar Siddiqi, a life-long teacher of physics and materials and science popularizer, is one of Pakistan's most active and oldest grassroots science awareness movements. The Lahore Science Mela (Festival) Series is its flagship activity that was initiated in 2017 in order to foster a scientific culture in the public of Lahore. The Ali Institute of Education (AIE) was established in 1992 with a primary goal of providing effective teachers to the schools of Pakistan through training programs.

The idea behind the science melas is to impact the public's outlook towards science, celebrate the idea that science belongs to everyone, catapult students to a new pedestal where they could think beyond science textbooks and classrooms, create a cultural melting pot of intellectual discussion and scientific inquiry by providing a meeting place for the minds, and to inspire the next generation of scientists and technologists in Pakistan. The word *mela* itself is of Farsi origin and means the mingling of ideas, peoples, and activities.

Alice's Wonderland of Science

The Lahore Science Mela 2019, which was a completely free event, was jubilantly received by the Pakistani public. In the science mela series, the KSS aims at creating and curating a temporary science museum, an *Alice's Wonderland* which could mesmerize and fascinate students and instill in them an appreciation and wonder of science. The Mela of 2019, the third large-scale event of its kind, harbored a diverse set of *performers* from around the country representing a potpourri of ideas in physics, life sciences and wildlife, chemistry and materials, robotics and artificial intelligence, health and the human body, minerals and geophysical exploration, satellites and radio communication, nuclear technology, optics and photography, road and traffic safety, aerodynamics and artificial intelligence.

Standing inside rocksalt.

Thousands of visitors, in particular children, thronged to the science-fest from across the country to the wide-reaching ground of AIE. For example, teams from Karachi and a large contingent from inner Sindh province galvanized the festival with their inventive gizmos on finger print classification, computerized printing machines, hydroponic aquaculture, patterns on marble. The vocational training college in Khairpur demonstrated recipes for creating visually appealing mathematical patterns. Rabbits, eagle-owls, and preserved human fetuses remained a major attraction for young nature enthusiasts, while ham radio and live signal reception from Pakistan's indigenous low-earth-orbiting satellites garnered interests from hobbyists.

Public school students attempt to burn money borrowed from Punjab's education minister. Clever chemistry foiled the attempt, luckily.

At the Lahore Science *Mela*, we saw multiple astronomers bring in some of the country's largest telescopes for viewing solar prominences which were, luckily, conspicuously seen on both days of the festival. On the sidelines there were animated discussions on astrobiology and search for life and Cosmic Perspective's meticulously designed planetarium showed stunning films on cosmology and our place, as humans, in the cosmic perspective.

Catching brain waves with EEG helmets.

A major theme on how this mela was designed by its inspirers was the connection between the macroscosm and the microscosm. So while telescopes beamed images from light-years across, our on-site microscopes showed micro-organisms, parts of insects, animal and plant tissue and different crystals. The idea of knowing about the hidden treasures inside the earth's interior, by showcasing rocks and minerals, some of the world's most antiquarian sea-fossils and crystals also resonated well with the theme of the festival, and furthermore, provided an impetus to investigate the under-represented discipline of geological sciences in the country.

Pakistan's space mission explained.

Stargazing has always remained an obsession at the Lahore Science Mela.

A child prodigy sets a time record for solving the Rubik's cube.

Chemical curiosities

With 2019 declared as the International Year of the Periodic Table, the Lahore Science Mela definitely emerged as the country's largest chemistry show. Thirty-six cherry-picked teams from all of Punjab's thirty-six districts were mentored and trained by KSS's volunteering chemists and life scientists into preparing jaw-dropping, insightful and wonder-inspiring chemical experiments.

The Lahore Science Mela harbored Pakistan's biggest live chemistry show.

For example, the team from Sialkot displayed chemical chameleons, Hafizabad's chemical snake danced to the tunes of snake-charmer's melodies, eager students from Chiniot were found busy extracting DNA, Jhelum glittered saucers with chemical decorations, Nankana demonstrated colors of copper, and Mandi Baha-ud-Din's team explored the facets of iron rust.

Earlier, these teams had converged in Lahore's National Museum of Science and Technology where the mentors, Dr. Muhammad Mustafa and Dr. Hira Sheikh guided them about chemical safety, the etiquettes of science communication, dramatizing scientific experiments while KSS's President, Dr. Saadat Siddiqi shared the philosophy behind the festival and explained that the festival is *not* an exhibition, rather a dynamic display of scientific phenomena. For student science exhibitions which largely revolve around making static artistic renderings of scientific phenomena—called 'models' in local parlance—bringing home the idea of making museum-worthy demonstrations and experiments,is no doubt a major and hitherto unfamiliar upgradation.

Science photographs on display at the LSM.

Spicing up the Lahore Science Mela, there was a science photography contest. This was segmented into three themes: the “moon and the dwelling”, “skills and the skillful”, and “weird and wonderful”. *Zaawiya* (translated as ‘perspective’) School’s dramatics club presented a science theatre in the Ali Auditorium whose central idea was based on a jury who decides whether planets become members of a solar club. Aamna Saleem’s team conducted a workshop on telescope making, and Science Fuse’s Lalah Rukh, a science fascinator, presented an immaculate science show on chemical reactions.

Firing rockets.

A portable science museum

Right in the middle of the vast field housing the Mela, stood KSS’s portable science museum. Designed by one of the authors (Sabieh), and Umar Hassan and expeditiously built by a team of instrument builders (Hafiz Muhammad Rizwan, Khadim Mahmood, Ayaz Mahmood), this museum was a small-scale embodiment of KSS’s underlying philosophy of organizing the Lahore Science Mela. Walk-in crystals welcomed the incoming visitors and provided an opportunity to feel what appears inside a periodic arrangement of atoms. A 30 ft long resonance machine, dubbed Gulliver's resonator, demonstrated standing waves as visitors watched in amazement.

Pendulums and wave machines were everywhere.

Rocks and minerals galore.

On the far corner of KSS's science pavilion, housed inside a dark room, the *Bait-ul-Muzlam* (the original Arabic for Ibn-al Haitham's *camera obscura*), one could witness machines producing interfering water waves, lasers projecting spiral patterns (built by students from Pakpattan—a town known for the resting abode of an accomplished Muslim saint), shadowgraphs and fluorescent crystals. The thumping sound of a 30 kg falling plate, incited by a 30 g seed in a multi-scale domino and inter-mixed with bursting roars of excitement from cheering crowd, reminded us of the optical illusionist whom we joyously observed as little children, as he performed outside the Bhatti Gate in the inner walled city of Lahore.

The graphene walkway.

Lahore has been known for its metal industry in the pre-colonial times. Ranging from Damascene swords to becoming the world's biggest producer of astrolabes, Lahore had it all. Over the centuries, these guilds run by family businesses have slowly withered away or crumbled in face of the onslaught of the industrial revolution. The Lahore Science Mela showcased several of these craftsmen highlighting the technological underpinnings and scientific principles of their scientific art and craft. Interestingly, the city is also home to one Ahmad Muhandis Lahori, the architect of the famous Taj Mahal. *Hast-o-Neest* (literally: "to be or not to be"), an institute of the traditional arts, joined hands with the KSS to unravel the mathematical and geometric foundations of Islamic architecture.

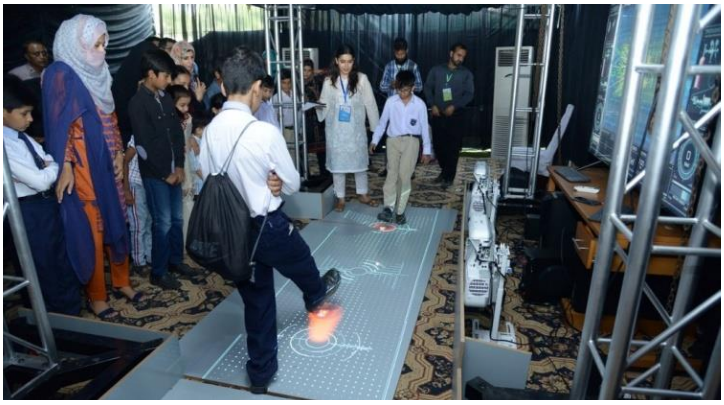
The mela also had a great representation from AIE where the trainee students exhibited their novel teaching methods through working models. Moreover, the Projects and Consultancy Department at the AIE attracted students from marginalized schools and under the department's supervision, the young scientists confidently showcased their experience with science in the laboratories and in the classrooms.

Traditional artists build their articles on site of the Mela.

Gamifying particle physics

KSS's coordination with Dr. Muhammad Sameed at CERN started in January 2019 who connected us with the Media Lab and introduced us to Media Lab's leader, physicist Dr. Joao Pequenao.Joao likes to call himself a 'recovering physicist' and his passion is to amplify physics, in particular particle physics, by using contemporary digital technologies to broad audiences around the world. In March 2019, we extended an invitation to CERN to handhold the building and exhibiting the Large Hadron Collider Interactive Tunnel (LIT). CERN accepted our invitation and we gleefully received Joao as he landed on Allama Iqbal International Airport in the early hours of 8 October 2019.

As soon as CERN's presence at the Lahore Science Mela was confirmed, our team comprising avid technologists Shahab Ahmed, Mubashra Manzoor and Abubakar Siddiqi was mobilized in Lahore to initiate the building of the LHC Interactive Tunnel. The KSS had never seen a project of this kind, both in terms of its financial outlay and sophistication. Under Joao's constant advice, Abubakar scuttled in game shops, electronics warehouses, shopping malls and party decorators and as soon as Joao arrived, and under his skillful leadership, we completed the building of the Tunnel to be eventually up at the Lahore Science Mela.



Playing football with protons inside CERN's LHC Interactive Tunnel.

In the meantime, the KSS assembled a team of young men and women from across the country who would be mentored and taught by the expert-in-residence. Joao taught Junaid Saif and his team the particulars of the Tunnel, gave a tour de force workshop on particle physics, the standard model, improvisation theatre and the art of eloquence for public engagement in science. This training has now left KSS with the capacity to carry on CERN's mission of propagating physics and educating and inspiring the next generation of scientists.

Students queue for entry into the LHC Interactive Tunnel.

The LHC Interactive Tunnel is a fully immersive gaming experience that uses accelerometers, motion sensors, short-throw projections on the floor, and a large TV screen on the backdrop,combined with gripping multimedia to educate visitors about particle accelerators, collisions and creation of new particles, the Higgs field, the Higgs boson and using hadrons for healing and therapy. On the occasion of the Lahore Science Mela, the Tunnel was deployed inside an air-conditioned tent on the festival's location.

What is the Higgs field?

KSS's Tunnel team.

Soon after curtains were raised on 9 am on the 12th of October, enthusiasts were siphoned into the chamber in groups of 30 to 50, leaving an estimated 4000 people directly impacted by the exhilarating multimedia experience. As visitors were awed by the performances of protons collisions, Higgs fields and hadron therapy, they also engaged in interactive discussions on topics ranging from the big bang and the expansion of the universe to its ultimate fate, the composition of matter and energy, the meaning of dark energy and dark matter and the origin of fundamental forces. We believe that the Tunnel has influenced and inspired thousands of young minds, instigating them into asking and wondering about all of these subjects, and considering science and physics as a potent medium to start answering some of the most critical questions about the universe.

Views from inside CERN's LHC Interactive Tunnel.

Furthermore, while demonstrators were busy dealing with the throngs of keen inquirers, Joao was often seen slipping out of the tent, only to mingle with the hundreds of students who immediately encircled him and asked him wide-ranging questions about particle physics, mysteries of the universe, elementary particles, gravity, black holes and perhaps, with questions bordering on religious doctrine and science. Joao had immediately acquired the status of a celebrity attending to continuous requests for visual autographs, i.e. selfies.

Dr. Joao Pequenao, CERN's emissary of science and an instant celebrity at the Lahore Science Mela.

Peek into the CERN's compact muon solenoid itself

In addition to the Tunnel, the KSS happily took up CERN's generous offer of participating in a virtual visit of the compact muon solenoid (CMS), one of the four major experiments being conducted at the world's largest particle physics lab.

CMS's virtual tour is in progress.

The first virtual visit of the CMS took place on 12th October, 2019 at 2 pm (Pakistan Time) in which around 300 school children and their teachers took part. The Urdu guides including Dr. Bilal Kiani, were live from CMS and explained the machinery and its working to the audiences. The audience were mostly school students.On the second day, the audience comprised of college and university students. We also gave the floor to Joao who, with his animated performance, described the myriad projects at CERN thus motivating the spectators of what they should expect in the guided tour.

Despite some technical difficulty in terms of internet connection, the virtual visit went on for two hours and included an extended question and answers session. The visit ended with a giveaway of the CMS Rubik Cube won by a 13 year-old who seemed to be quite knowledgeable about CERN's research. The feedback forms solicited from the virtual visits indicated that more than 90% of the audience believed that the tours had contributed to their learning. In particular, the audience felt home with and appreciated the idea of having Urdu guides for better communication.

Dr. Joao Pequenao leading the CMS virtual tour from Lahore.

Between the lines

Powered by more than fifty volunteers and four science communicators (Charisma Wafee, Hamza Waseem, Nimra Khurram and Salman Mahmood), the planning and design of the Lahore Science Mela was a case in project management itself.

There are so many stories to tell, so many lessons learnt. But what catches our attention the most is the story of the human condition.The performing school students and their teachers, who mostly come from several hundreds of miles away from Lahore, had to face all kinds of financial and bureaucratic hardships in developing their experiments and especially in light of the high standards we had set for them. The girls, who comprised exactly half of the performing government schools, had to travel with their female teachers, leaving behind families, stay for at least a couple of nights and at the same time, live up to the quality and scale of the Mela. In Pakistan, this is easier said than done.

Though Punjab's School Education Department, which is the country's largest civilian organization with half a million staff members, had cooperated with us on every count, the top-down bureaucratic process that trickles down to the schoolteacher through many layers of officialdom and the backward route upwards, adds to psychological stress, confusion and delays. We have now tried to capture some of these stories through snippet videos being prepared by our media partner Scientwist.

The stories have not ended here. We are determined to take this experiment all around the country. Using Urdu as the mode of communication and relying on the masterful strokes of our artists (Abubakar, Hadiqa and Kashif), we have made an attempt to made science accessible. "Science for the masses" has been our motto throughout this campaign. The KSS has also cherished the ideals of "science for everyone" in its more than twenty years long life. But this also means we must come out of our cocoons of comfort and take science to the doorsteps of the common man and talk to him on *his* terms. The Lahore Science Mela is one step in that direction.

Khwarizmi Science Society's team, architects of the Lahore Science Mela.

A Platform Economy Approach to Evaluating Science Diplomacy

Muhammad Adeel (Career Diplomat, Ministry of Foreign Affairs)

Science diplomacy as an academic concept and policy practice has evolved extensively since the American Association for Advancement of Sciences (AAAS), and the Royal Society presented their three-tier typology of Science in Diplomacy, Diplomacy for Science and Science for Diplomacy[1]. The mainstreaming of global challenges such as climate change and food security have also propelled the discussion on the science-policy-society interface in providing solutions. Furthermore, various interpretive schemas have emerged along the lines of the 'boundary problem'[2], devising a curriculum for science diplomacy competencies[3], pragmatic framing involving national, cross-border, and global interests[4] , and an international relations framework on power, among other definitional attempts[5]. So, a generally fragmented epistemology of theory and practice of science diplomacy is prevailing presently.

Many of the positive outcomes[6] of science diplomacy such as international scientific collaboration, attaining socio-economic development, bridging gaps between innovation stakeholders, connecting scientific diasporas[7], and reducing conflict come from science diplomacy's ability to act as a platform. In their pathbreaking work, '*Platform Revolution*'[8], Geoffrey Parker, Marshall Van Alstyne and Sangeet Choudary have extensively explored the rise of the platform economy as a business and an organizational model. This epoch was manifested by the rise of platform businesses such as Facebook, Airbnb, and Uber. Platform businesses facilitated the exchange of goods, services, and values in an unprecedented manner. A crucial takeaway from their study were the 'network effects' that platforms create in form of value, new forms of markets and previously unidentified levels of user interactions[9]. This management literature-related, and commercialization-centric approach has very relevant applications in reconciling various existing typologies of science diplomacy with a 'platform' approach.

Taking the lead from '*Platform Revolutions,'* the essence of a platform lies in its core interaction which includes a tripartite engagement between the 'participants', the 'value unit', and the 'filter'. The core interaction of science diplomacy primarily involves interactions between scientists and diplomats and the resultant value they can create. Based on the professional setting concerned, each (diplomat/scientist) can be a producer and a consumer. A scientist can be a producer in a research/scientific ecosystem or a consumer in a policy/diplomacy setting and adopt both roles in a science diplomacy setting. The value unit includes a suite of deliverables based on the interaction of science and diplomacy. For instance, within the Ministry of Foreign Affairs setting, the value unit can be science advice rendered or promotion and marketing of local technology products/services in global markets. Lastly, the filter manages the exchange of information. Platforms are also defined by robust feedback loops, allowing it to self-edit and optimise for further value creation.

The benefits accrued by platforms such as reduction in information asymmetries, creation of new markets, reduction in costs, increase in productivity, matchmaking, and flexibility for workers have similarities with the positive externalities created by science diplomacy-based interactions. The reduction of silos through bridging gaps reduces inefficiencies and transaction costs. Similarly, engagement of scientific diaspora has resulted in new forms of innovation opportunities and the genesis of knowledge networks. Furthermore, platforms act as a creation infrastructure and a coordination mechanism. This effect is quite akin to how science diplomacy creates new forms of interactions between scientists and diplomats and provides a new coordination mechanism for relevant Ministries (Foreign Affairs, Science & Technology etc) and research infrastructure for scientific discovery, and governance of transboundary resources.

The various deliverables of science diplomacy such as science advice, science diplomats, new bilateral and multilateral scientific governance structures, forecasting and anticipatory tools[10] and scaling of scientific infrastructure along with interdisciplinary skillsets are very much a platform ecosystem. Such an approach will also enable an empirical approach to studying various science diplomacy efforts. The metrics for analysing platforms such as number of users, matchmaking, kind of interactions, value and skill competencies, and access to deliverables, can also be applied to studying science diplomacy efforts on a case-by-case basis.

There is also a significant regulatory aspect related to complementarity between platforms and science diplomacy. Since science diplomacy populates diverse stakeholders by virtue of its multidisciplinary nature, it leads towards an evidence enabled regulatory discourse. This aspect is highly relevant for regulations of new and emerging technologies, which suffer from a lag between innovation and risk-appropriate regulatory regimes[11].

From a practitioner-driven literature perspective, a platform approach can also potentially enable data-driven discussions along the lines of competition and cooperation. One critique of existing science diplomacy-related literature has been its tendency of '*romancing science for global solutions*'[12]. There is a whole power centric and statist lens to the nexus of science, technology and international affairs that is yet to be substantially expanded upon under the science diplomacy framework.

Since there is no common understanding of science diplomacy, a platform approach potentially allows a study of varying expectations and meanings among different actor groups[13]. A platform approach can complement other empirical science diplomacy evaluation designs such as policy instrumentation studies[14] or sociotechnical imaginaries-based classification[15].

Lastly, there is a whole entrepreneurial dimension to the platform approach that science diplomacy practitioners can benefit from. With the rapid emergence of converging technologies and their cross sectoral applications, science diplomacy as a platform allows for norm entrepreneurship to enable equitable access, substantive regulatory dialogue, and an informed sociotechnical future. Furthermore, tools derived from new and emerging technologies such as artificial intelligence are aiding diplomatic processes[16] and enabling new avenues for science diplomacy 2.0[17]. As more diverse stakeholders enter the science diplomacy landscape, there is a need to use the platform approach to create inclusive, value laden and sustainable architectures.

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About Science Diplomacy Division @SciDipPak

Cognizant of the potential of science diplomacy to advance Pakistan's national interests and participate effectively in the global science and technology ecosystem, the Ministry launched its Science Diplomacy (SD) initiative in 2019 with the designation of a Focal Point (Science Diplomacy Division) to act as a liaison between national science and technology (S&T) stakeholders and international partners.

Ministry's SD initiative focuses on thematic areas, institutions, and country-specific collaborations to provide direction to our science diplomacy agenda. Furthermore, a special focus has been laid on leveraging science diplomacy to implement Sustainable Development Goals (SDGs), all of which have a strong science and technology component.

About COMSTECH @OIC_COMSTECH

COMSTECH the Ministerial Standing Committee on Scientific and Technological Cooperation of the OIC (Organization of Islamic Cooperation) was established by the Third Islamic Summit of OIC held at Makkah, Saudi Arabia in January 1981. The President of Pakistan is Chairman of COMSTECH. The core mandate of COMSTECH is to strengthen cooperation among OIC Member States in science and technology (S&T), and enhance their capabilities through training in emerging areas, undertake follow-up-actions and implementation of the resolutions of the OIC, and to draw up programs and submit proposals designed to increase the capability of the Muslim countries in science and technology (S&T). The ultimate aim is to build and nourish a scientific culture in addition to using S&T as a major contributor to socio-economic development and rapid industrialization.

Further details

- https://mofa.gov.pk/science-for-sustainable-development/
- https://www.comstech.org/

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