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Reorganization of Pakistan's Science and Technology Enterprise

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ABSTRACT

Ability of any modern society to develop and fully exploit advancements in Science and Technology (S&T) is critical to its long-term prosperity. While public investments in S&T throughout the developing world are abysmally low, what is more disturbing is the ineffective use of scarce resources. In the absence of a clear understanding of how investments in S&T enterprise improve the quality of life of citizens and enhance their security. It is not surprising that developing countries struggle to formulate and implement knowledge-driven, cost-effective, climate resilient development strategies. Changes in climate, natural disasters and increasing levels of environmental pollution are likely to aggravate the governance challenge in developing countries. This paper outlines key pillars of a reorganization strategy that aims to reenergize Pakistan's S&T enterprise with the objective of tackling the complex array of societal challenges that changes in environment are likely to exacerbate. While S&T enterprise encompasses public and private sector institutions of higher education, research and development, the focus of this research paper is on the Ministry of Science and Technology – the federal government entity responsible for planning and management of scientific research and technology development in Pakistan. After briefly describing the history and evolution of the United States (US) S&T enterprise, the social and geopolitical context in which Pakistan has planned its past investments in science, technology and higher education is examined. The author argues, that environmental change and degradation poses a serious risk to the economic wellbeing of a state and its people. Any effective strategy aimed at mitigating and managing the adverse impacts must have it at its core the goal of building and sustaining both public and private sector institutions capable of seeking and fully exploiting relevant scientific knowledge and technology in pursuit of their respective mission.

1. Introduction

Ability of any modern society to develop and fully exploit advancements in Science and Technology (S&T) is critical to its long-term prosperity. As a consequence, governments, development aid agencies, and non-profit organizations are endeavoring to spark technology-driven, innovation led growth [1]. The United States (US) S&T enterprise remains the envy of the world, and many attribute US stature as the indispensable world power to its success [2].

Technology driven economic growth is undoubtedly a complex phenomenon [3, 4]. At its core are values, culture, policies, law and regulations that enable transactions among diverse agents within a system that is comprised of people, institutions and enterprises. Despite recent advances in our understanding of the "innovation ecosystem" [1, 5, 6], there is little consensus on any particular set of policies and strategies that would ensure equitable and sustainable economic growth through effective use of public investments. While public investments in S&T throughout the developing world are abysmally low, what is more disturbing is the ineffective use of scarce resources. Debates on policy and strategy often narrowly focus on the science budget, ignoring other factors that are critical for science-led economic growth [7]. In the absence of a clear understanding on what kind and what level of investment in S&T enterprise are most effective to improve the quality of life of citizens and to enhance their security, developing countries struggle to formulate and implement knowledge-driven, cost-effective and climate resilient development strategies.

Natural disasters and environmental pollution tend to complicate, and in some cases, aggravate the governance challenge in developing countries [8, 9]. Expected changes in climate will likely degrade the performance of human-engineered systems [10], such as food production, water management, energy, transportation, etc., pushing back efforts aimed at reducing inequality, strengthening the middle class and improving the quality of life of the most vulnerable.

Fundamentally a problem of environmental protection and technology, the defining feature of the climate change challenge is the complex interaction of population, demography, politics, culture, technology, international relations and nature. Adapting to a changing climate, or mitigating its negative impacts requires active participation from all segments of the society. Incomplete or contradictory knowledge regarding the problem and possible solutions, the large economic burden of any deliberative action and its relationship with other societal challenges makes it an extremely difficult problem to solve. In addition to access to capital and technology, the ability of institutions, teams and individuals to think independently and act collaboratively is crucial to success. The potential benefits of trans-disciplinary research require S&T organizations that are diverse and adaptable. Complexity of the challenge makes reductionist approach ineffective, requiring public and private sector

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organizations to continuously reinvent themselves, breakdown silos, and value organizational resilience as much as efficiency [11, 12].

This paper outlines key pillars of a reorganization strategy that aims to reenergize Pakistan's S&T enterprise with the objective of tackling the societal challenges that changes in the environment are likely to exacerbate. While S&T enterprise encompasses public and private sector institutions of higher education, research and development, the focus of this research paper is on the Ministry of Science and Technology – the federal government entity responsible for planning and management of scientific research and development. After briefly describing the history and evolution of the US S&T enterprise, the social and geopolitical context in which Pakistan has planned its past investments in S&T examined. The author argues, that environmental change and degradation pose a serious risk to the economic wellbeing of a state and its people, and any effective strategy aimed at mitigating and managing the adverse impacts must have it at its core the goal of building and sustaining both public and private sector institutions capable of seeking and fully exploiting relevant scientific knowledge and technology in pursuit of their respective mission.

2. History and Evolution of US S&T Enterprise

The US Congress laid a solid foundation for the success of the US S&T enterprise almost 150 years ago with the passage of Morrill Act in 1862 [13]. This farsighted legislation created a nationwide system of land grant colleges, giving the federal government direct role in supporting higher education. Although public investment in R&D remained relatively modest until the start of the Second World War - the US federal government financed only one-fifth of the US R&D [14] - *The Morrill Act* contributed to the emergence of an ecosystem comprising of public and private sector institutions that were collectively capable of game-changing innovations at a pace that adversaries could not match. Some of the most notable advancements during the war were radar, the proximity fuse, penicillin and the atomic bomb. It is not surprising that by the end of the Second World War, the US emerged as the preeminent world power.

The remarkable contribution of science to the war [15] resulted in a virtual consensus within society on the importance of continued advancement in S&T as a means of ensuring long-term economic prosperity and security. In November 1944, President Franklin D. Roosevelt addressed a letter to Dr. Vannevar Bush [16], his science advisor, seeking recommendations on how lessons learned from the mobilization of science for war can be applied for achieving peacetime prosperity. The resulting report, *Science – The Endless Frontier* was submitted to President Harry S. Truman on July 5, 1945 [17] and is regarded as the cornerstone of post–World War II US science policy. To govern the investment strategy, the report laid out three fundamental principles which have endured through the last seven decades: (1) the Government must act as the principal source of funding for basic science; (2) basic science should be located primarily within universities that combine research with education; and (3) the allocation of funds for particular projects should be made by independent scientific experts, and government should only concern itself with allocating funds across broad categories of science [2]. It is not therefore by accident that US government institutions and universities perform about 64 percent of the basic and about 41 percent of applied research, whereas industry performs only 21 percent of the basic, 54 percent of the applied research and 77 percent of the development [18].

In the early 1950s, the US government took several major initiatives, including creation of the National Science Foundation (NSF), and a ten-fold increase in funding for the National Institutes of Health (NIH). However, it was not until the launch of Sputnik by the Soviet Union in 1957 that investment in S&T gained a strategic dimension. Within months, implementation of the strategic vision articulated in Science – *The Endless Frontier* began in earnest with the creation of National Aeronautics and Space Administration (NASA) [19] and Defense Advanced Research Projects Agency (DARPA) [20]. While DARPA's purpose was to conduct Research and Development (R&D) to meet military needs and ensure against future "technological surprise," NASA was created to ensure that US did not fall behind the Soviet Union in aerospace research and development. President Kennedy's decision to send people to the Moon, accompanied by a 15-fold increase in NASA budget between 1960 and 1966 [21] had a transformative impact on the US S&T enterprise. The use of science to address societal challenges and achieve economic prosperity took hold over the next two decades. Health concerns related to environmental pollution and the energy crisis led to the creation of United States Environmental Protection Agency (EPA) in 1970 and the Department of Energy in 1977.

The US government's defense and nondefense R&D budgets have remained remarkably stable at 10 and 12 percent of total discretionary spending [22]. US discoveries in basic research have yielded more than 330 Nobel Prize awards, almost 40 percent of the world's total and more than the next 4 highest countries combined [2]. The annual rankings released by The Times of London listed 7 US universities among the top 10, and 18 among the top 25. Academic institutions and National Laboratories that operate as Federally Funded Research and Development Centers (FFRDCs) have remained strongly committed to high risk basic and early applied-research that enable creation of a common platform on which new industries can be built through injection of private capital and open competition. The outcome of these investments includes advanced breast cancer screening that identifies tumors in time for treatment; invention and manufacturing of the artificial heart pump; navigation, communication and earth imaging satellites; and the Internet. In 1969, DARPA-funded researchers were the first ones to develop Internet Communication Protocols (IP), many of which are still used. Key to the development of this technology was funding provided by NSF for the creation of a NSFNET [23]. The 50,000 bits per second network allowed scientists and engineers around the country to access supercomputers at various US universities free of cost. It was decommissioned in 1995, after private firms built their own networks and started providing commercially viable network communication services. By 2016, the global information technology industry comprised of hardware, software, services, and telecom services surpassed $3.4 trillion [24].

Scientists and political leaders, who set the US on its post-World War II R&D path, could not have foreseen the extraordinary results achieved by the US S&T enterprise - a fact that was acknowledged by NASA in its Long-Range Plan released in 1959. It stated, "Space science activities cover the frontiers of almost all the major areas of the physical sciences and these activities thus provide support of the physical sciences in specific applications in the field of electronics, materials, propulsion, etc., will contribute, directly or indirectly, to all subsequent military weapons developments and to many unforeseen civilian applications".

Presidential leadership [25], generous congressional support, and collaborative relationship between government, academia and the private sector have been the key to success. Reliable funding for S&T at the US Department of Defense during the cold war, together with favorable immigration policies, and general confidence in the economic and legal systems has helped the US remain a choice destination for talent and investment. Daniel Sarewitz [26] has argued that creativity unleashed to satisfy military needs was largely responsible for scientific advancements that have transformed the post-world war global order. It is also true that broader societal impact of these advancements would not have been possible without the contribution of the US private sector, which has exceptional ability to exploit publicly funded scientific advances - iPhone being the most vivid example. Of the thirteen areas of technological advancements that were essential to the development of the iPhone, eleven including the microprocessor, the Global Positioning System (GPS), and the Internet can be traced back to vital military investments in research and technological development [1]. Economist Mariana Mazzucato and colleagues argue that in the history of modern capitalism, the State has not only fixed market failures but have also actively shaped and created markets [1]. They suggest that the private sector only finds the courage to invest after high-risk public-sector investments have borne fruit and warn that misunderstanding and ignoring the positive role of the State may result in the emergence of an innovation ecosystem whereby risks are socialized, and rewards are privatized, leading to economic growth that is non-inclusive, the exact opposite of the desired impact.

3. Pakistan's Scientific Enterprise

Pakistan gained independence in 1947. In the riots that occurred, between one to two million people were killed, and fifteen million were displaced – the largest mass migration in human history [27]. Within fifteen years of that event, Pakistan had launched a serious quest for excellence in S&T. The driving force behind the effort was Dr. Abdus Salam, a Pakistani theoretical physicist [28] who served as the Science Advisor to the President of Pakistan from 1960 to 1974. Salam shared the 1979 Nobel Prize for Physics with Sheldon Lee Glashow and Steven Weinberg for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles [29]. Besides serving as the first Member (Technical) of the newly established Pakistan Atomic Energy Commission (PAEC), he was instrumental in the establishment of Space and Upper Atmosphere Research Commission (SUPARCO), and the Pakistan Institute of Nuclear Science and Technology (PINSTECH) – institutions that went on to play a pivotal role in the advancement of space and nuclear technology in Pakistan. Fully aware that establishing a successful S&T enterprise was not possible without a well-educated and trained workforce, Dr. Salam relentlessly advocated and successfully arranged scholarships for about five hundred physicists, mathematicians and scientists from Pakistan for doctoral studies. The returning scholars became the core around which Pakistan's S&T enterprise was built.

The 1971 India-Pakistan war, Indian nuclear tests in 1974, the election of populist government led by the mercurial Zulfiqar Ali Bhutto, and the difficult US-Pakistan relations were the driving forces behind the launch of a covert nuclear program [30]. Successive political and military leaders saw full access to nuclear technology as a national security imperative. Clarity of mission, access to resources, and adequately educated and trained workforce ensured that the lead organization – PAEC, not only successfully achieved the mission that was assigned to it, but went beyond it, applying nuclear technology to satisfying needs of health and agriculture sectors. The eighteen Nuclear Medicine and Oncology Centers (NMO) spread across the country provide patients state-of-the-art diagnostic and treatment facilities either free of charge or at subsidized rates. Similarly, Agriculture Research Centers established by PAEC have made significant contribution to increase agriculture productivity through the application of nuclear technology. Efforts have resulted in the introduction of new crop varieties, effective pest control, improved plant nutrition, efficient water management techniques, better animal health, and a reliable food decontamination and preservation.

S&T institutions continued to proliferate throughout the 70s, 80s, and 90s (Table 1 & Table 2). However, with the exception of PAEC and the covert nuclear program, civilian S&T institutions did not receive adequate government support. Without quality public education, adequately trained mid-level managers, ineffective leadership, and the inability to attract and retain talent through a right mix of incentives and accountability, it was not surprising that most of these institutions were unable to achieve the objectives for which they were established. The decline in the public education system was felt most by the armed services that were scrambling to overcome the challenges that emerged as a result of US sanctions against Pakistan's nuclear program.

Table 1: Government organizations engaged in science, technology and research, development and engineering services within the administrative control of MoST.

Name	Purpose
Pakistan Council for Scientific and Industrial Research (PCSIR)	Promote and guide scientific and technological research in respect of problems connected with the establishment and development of industries in Pakistan.
S&T Commercialization Corporation of Pakistan (STEDEC)	Facilitate Public Sector R&D organizations in commercialization of indigenously researched products, processes and technologies. STEDEC generates revenues through its commercial activities and no development or non-development budgetary allocation is made to STEDEC in the Federal Government budget.
Pakistan Council for Research in Water Resources (PCRWR)	Undertake research related to irrigation, drainage, surface and groundwater management, groundwater recharge, watershed management, desertification control, rainwater harvesting, water quality assessment and monitoring, water conservation and treatment technologies.
Pakistan Council for Renewable Energy Technologies (PCRET)	Established by merging the National Institute of Silicon Technology (NIST) and the Pakistan Council for Appropriate Technologies (PCAT). It is responsible for coordinating R&D in renewable energy technologies.
National Institute of Oceanography (NIO)	Conduct, coordinate and promote research in oceanography and marine sciences for the purpose of protection and conservation of marine environment including exploration, exploitation, and management of marine resources.
Pakistan Science Foundation (PSF)	Promote and finance scientific activities having bearing on the socio-economic needs of the country. It is headquartered in Islamabad and has two subsidiary organizations: Pakistan Museum of Natural History (PMNH) and Pakistan Scientific and Technological Information Center (PASTIC).
National University of Science and Technology (NUST)	A research university established by merging College of Aeronautical Engineering (CAE) & Military College of Engineering in Risalpur; College of Electrical & Mechanical Engineering (CEME) and Military College of Signals (MCS) in Rawalpindi; and Pakistan Navy Engineering College, Karachi
Commission on Science and Technology for Sustainable Development in the South (COMSATS) Headquarters	COMSATS is an intergovernmental organization with its permanent Secretariat based in Islamabad, Pakistan. Established in 1994, the organization comprising 26 Member States, strives to promote South-South cooperation in the fields of Science and Technology that are most relevant to socio-economic development.
COMSATS University	Established to promote Information and Communication Technologies by COMSATS, the University is one of the largest academic institution with more than 33,000 students across eight campuses.
COMSTECH (Organization of Islamic Cooperation Committee on Science and Technology)	The Ministerial Standing Committee 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. 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.
National Institute of Electronics (NIE)	Undertake design and development in emerging areas of electronics and to acquire know-how in advance disciplines. Institute has the mandate for pilot production of electronic equipment, electronic components and software. It disseminates knowledge of electronic technologies to common users.
Pakistan Engineering Council (PEC)	Responsible for regulating the engineering profession in the country. Statutory functions include, registration of engineers, consulting engineers, constructors/operators and accreditation of engineering programs offered by universities/institutions, ensuring and managing of continuing professional development.
Pakistan Council for Science and Technology (PCST)	Providing the Government advice on S&T policy and plans, conduct regularly evaluation of scientific research through bibliometric and peer review techniques, undertake strategic R&D planning through expert committees.
Pakistan National Accreditation Council (PNCA)	Agency responsible for performing conformity assessment of laboratories and certification bodies under World Trade Organization (WTO) rules.

Table 2: Government organizations engaged in science, technology and research, development and engineering services that are not within the administrative control of MoST.

Name	Description	Parent Ministry/ Division
Geological Survey of Pakistan (GSP)	An autonomous and independent organization responsible for advancing the field of geology and geosciences through systematic study of Pakistan's landscape, its natural resources, and the natural hazards that threaten it.	Ministry of Energy
National Engineering Services of Pakistan (NESPAK)	Established by the Government of Pakistan as a Private Limited company, NESPAK was created to ensure world class engineering and consulting services to government and private sector enterprise	Ministry of Energy
Alternate Energy Development Board (AEDB)	Responsible for facilitating, promoting and encouraging development of Renewable Energy in Pakistan at an accelerated rate.	Ministry of Energy
Pakistan Meteorological Department (PMD)	A scientific as well as a service department responsible for providing weather information to public and private sector organizations.	Cabinet Secretariat/Aviation Division
Global Change Impact Studies Center (GCISC)	Global Change Impact Studies Centre is a dedicated research institute for climate change studies in Pakistan. The Centre is mandated for national level R&D effort, capacity building, policy analysis, information dissemination and assistance to national planners and policymakers on issues related to past and projected future climatic changes in the country.	Ministry of Climate Change

Under the Pressler Amendment, the US government cancelled the sale of F-16 aircraft [31], forcing the Pakistan air force to look for alternatives.

Realizing that technology development and indigenization efforts are unlikely to be successful without an adequately educated workforce, the armed services established the National University of Science and Technology (NUST) in 1991 and began the process of reorganizing its academic and research institutions. Domestic political instability, international blowback of the Kargil conflict, nuclear tests, US India defense cooperation, 9/11 attacks, and the subsequent invasion of Afghanistan further increased the sense of anxiety within the Pakistani military establishment. The military government under General Pervez Musharraf initiated reforms in higher education, establishing the Higher Education Commission (HEC) in 2002, tasking it with the responsibility of increasing accessibility and improving quality of higher education and research in Pakistan [32]. During his tenure, Pakistan's annual investments in higher education rose from $65 million in 2001 to $205 million in 2005 – a four-fold increase in four years [33].

By 2015, the HEC budget swelled to $862 million [34]. Enrollment in public and private sector universities (including distance learning programs) increased from 276,274 in 2001 to 1.29 million in 2015. Over 6,000 students were awarded overseas scholarships [35]. The budget for the Ministry of Science and Technology - the institution responsible for articulating and managing federal government investment in S&T saw a substantial increase as well [36]. It is important to mention that despite these budget increases, Government expenditure on education as a percentage of GDP averaged 2.3 percent from 1971 to 2017 [37].

Another significant step by the military government was to place PAEC and SUPARCO under the administrative control of the Strategic Plans Division (SPD), an entity that serves as the Secretariat for the National Command Authority (NCA) responsible for the security of nuclear weapons, delivery systems, and related technologies. The action was prompted by threats to nuclear facilities and the desire to reenergize the scientific enterprise, primarily in pursuit of defense and national security objectives. Until today, SPD exercises administrative control over PAEC, SUPARCO, the National Engineering and Scientific Commission (NESCOM), and the National Development Complex (NDC). The mission of these R&D organizations is to promote proficiencies in nuclear, ballistic missile, and conventional military hardware.

At present, Pakistan's civilian S&T enterprise comprises of, and is organized around the MoST and the HEC, with the Planning Commission of Pakistan (PCP) responsible for managing the overall strategic direction through the project approval process instituted by the Federal government. Like every other ministry, MoST and HEC submit requests for funding to the PCP, which performs a detailed assessment to ensure that the project document contains all the information necessary for its evaluation, and the project is aligned with government priorities. Once satisfied that the decision regarding the project can be effectively deliberated upon, the PCP presents the project for approval to the Central Development Working Party (CDWP). The CDWP is authorized to approve projects less than PKR 3 billion. Projects whose estimated cost exceeds this amount undergo further review by the Executive Committee of the National Economic Council (ECNEC). Constituted under Article 156 of the Constitution, the National Economic Council (NEC) is the highest policy formulation body. It is chaired by the Prime Minister, and its members include the Chief Minister of each province, one member nominated by each of them, and four members nominated by the Prime Minister. Both CDWP and ECNEC are intended to streamline the project approval process. While the Rules of Business [38] allow PCP to monitor implementation of projects after they are approved, in practice the lack of subject matter expertise within PCP prevent it from undertaking any meaningful technical or strategic oversight. Federal ministries which are meant to oversee S&T executive agencies also lack technical expertise. Ministries are generally headed by an individual who is member of the National Assembly and the federal cabinet and enjoys the title of the Federal Minister. The administrative management of the department is led by a senior civil servant, with the title of Secretary, who also serves as the chief financial officer. The Chairman of HEC is appointed for a three-year term by the Prime Minister of Pakistan and is assisted by an Executive Director.

4. Key Observations

The purpose of briefly describing the history, context, and evolution of the US scientific enterprise was not to suggest that Pakistan should emulate that path, but to gain a more nuanced understanding of approaches and policies that have contributed to success. It is observed that:

i. Establishing and sustaining a successful S&T enterprise capable of addressing the perpetually changing national needs is a multi-decadal endeavor. It requires a collective vision that is cultivated and nurtured by a central authority, consistent political support, meaningful collaboration, and/or competition across disciplines and institutions.

ii. National security is a legitimate and powerful driver for long-term investments in S&T infrastructure, bringing purpose and focus to the entire effort. Ensuring that defense related investments in S&T provide broader socio-economic benefit requires government to institute personnel, procurement and other policies and programs that encourage open and transparent competition and opportunities for collaboration.

iii. Resource constrained environments benefit from a balanced portfolio of investments in basic and applied science; engineering and humanities; between primary, secondary and higher education; and between pursuit of common good and private profit. Achieving this balance requires a deep contextual understanding of the socio-political-technological system and how it may evolve.

iv. Effective solutions to complex societal problems require a web of partnerships that integrate knowledge, tools and ways of thinking aimed at translating scientific advances into innovative products and services. Maturation of these partnerships takes persistent effort and consistent government support.

v. Critical to success are well managed, adequately funded, autonomous, transparent, and accountable institutions committed to their assigned mission, capable of attracting and retaining talent, and initiating and managing partnerships.

5. Societal Challenges and the Role of Science

Strategically located in the foothills of the Himalayan mountain range, Pakistan continues to face serious socio-economic and security challenges. It is the seventh largest country in the world, home to 200 million people, thirty five percent of who are under the age of eighteen [39]. The median life expectancy is 66 years [40]. Fifty six percent of the population relies on biomass burning for their energy needs [41] and while Pakistan has made major gains in eliminating open defecation, more than a third of Pakistanis still lack adequate sanitation facilities [42]. According to the Pakistan Demographic and Health Survey conducted in 2013 [43], almost 53,000 children less than five years of age die because of diarrhea, a disease which is directly linked with poor quality water, sanitation and hygiene. The national Gross Domestic Product (GDP) is estimated at approximated $271 billion, with services, industry, and agriculture contributing 60.2, 20.9, and 18.9 percent to the national economy respectively [39]. Agriculture still employs 44 percent of the labor force and consumes 95 percent of the water withdrawal [44]. While Pakistan's economy has grown at an average rate of above five percent since 1952 [45], its Human Development Index (HDI) stands at 0.562, a value that is well below the average value of 0.638 for countries in South Asia that include India and Bangladesh [46]. HDI is a measure of average achievement in three key dimensions of human development: health, education and standard of living, which are assessed by estimating life expectancy at birth, number of years of schooling for the population aged 25 and above and the Gross National Income (GNI). In Pakistan's case, the inadequate level of human development is a reflection of persistent challenges related to taxation and governance that has eroded government's ability to plan and deliver essential services.

It is clear that problems facing Pakistani state and society are complex and do not lend themselves to easy solutions. Potential for cascading failures is significant as well. A key challenge for government is to ensure delivery of essential services. Failure to do so weakens the State, emboldening extremist groups as they search to establish influence and control over people and territory. Millions of young Pakistanis are without jobs or regular incomes. Changes in climate are likely to exacerbate societal challenges and complicate the search for solutions. A large population without the financial capacity to cope with the negative effects of climate change, dependence on agriculture as a source of revenue and employment, and limited capacity makes the Pakistani population highly vulnerable to extreme weather anomalies and other natural disasters [47].

These risks were evident when in 2005, an earthquake measuring a momentum magnitude of 7.6 and had a maximum Mercalli intensity of VIII (Severe) struck northern Pakistan, leaving 2.8 million people without shelter, killing 73,000 and severely injuring another 70,000 [48]. While still recovering, heavy rains fell over the Upper Indus main stem and adjoining tributaries of the Kabul River in July and August of 2010 [49, 50], destroying homes and infrastructure and displacing more than 20 million people. While the total recovery and reconstruction costs were estimated at around $9.5 billion [51], the total economic impact of flooding to rural livelihoods, agricultural output, industrial input and infrastructure was estimated at $43 billion [51]. The 2010 flood damage cost was approximately two percent of Pakistan's Gross National Product (GNP) and almost thirty percent of its tax revenue. In comparison, damages resulting from hurricane Sandy were estimated at $70 billion, which is 0.4 percent of the US GNP [52].

The expected increase in intensity and frequency of extreme weather events has the potential to wipe out decades of socio-economic progress. Natural disasters expose the cumulative implications of many earlier decisions. The unusual scale of destruction highlighted systemic institutional failure spread over decades. Weak enforcement of zoning regulations, deforestation caused by illegal logging, unplanned expansion of housing and transportation infrastructure, absence of dams, large-scale or subsistence agriculture farming, etc., are all thought to have contributed to greater than expected damage during the 2010 floods [53].

Compared to natural disasters, damage caused by persistent environmental pollution is a more sinister problem with much larger socio-economic consequences. According to the World Bank, environmental degradation costs Pakistan 6 percent of its GDP [54]. Almost 80 percent of the environmental damage costs are associated with air pollution, inadequate water supply, sanitation and hygiene. In comparison, annual economic impact of flooding in Pakistan is estimated between $1.2 to 1.8 billion, equivalent to between 0.5 to 0.8 percent of national GDP [55]. A reduction in the overall burden of disease through enforcement of environment laws will potentially reduce the cost that government and individuals incur treating these illnesses. Given the size of public and private sector health care spending, the economic benefits of pollution control are likely to be substantial.

Preventing and responding to natural disasters, mitigating environmental pollution, and adapting to changes in climate are societal challenges of incredible complexity. Any action or strategy that is not informed by credible scientific analysis will likely turn out to be either inefficient or make the problem harder to solve. To fully benefit from scientific advancements the government must shift from opinion-based policy making that is driven by ideology, prejudices, or conjecture to a more systematic approach referred to as evidence-based policy making, which places the best available evidence at the heart of policy development and implementation process [56]. A transparent decision-making process and demand for knowledge and insight creates the necessary pull on public sector research organizations, academia and the private sector, which then have an incentive to invest in technology, personnel and partnerships that allow them to satisfy the needs of their potential customers. The resulting competition and/or collaboration leads to the emergence of an ecosystem that is capable of addressing the evolving needs of a society and nudge it on the path of sustainable and equitable economic development that does not jeopardize public health and the natural resource base.

The author believes that Pakistan's social and geopolitical challenges demand that the federal government initiate a systematic effort to reorganize Pakistan's S&T enterprise aimed at enhancing the ability of public and private sector institutions to exploit technological advancements in pursuit of their goals. The effort will build on more than fifteen years of investments in higher education, allow more effective use of scarce resources, and enable business – big and small, to fully exploit the opportunities under CPEC.

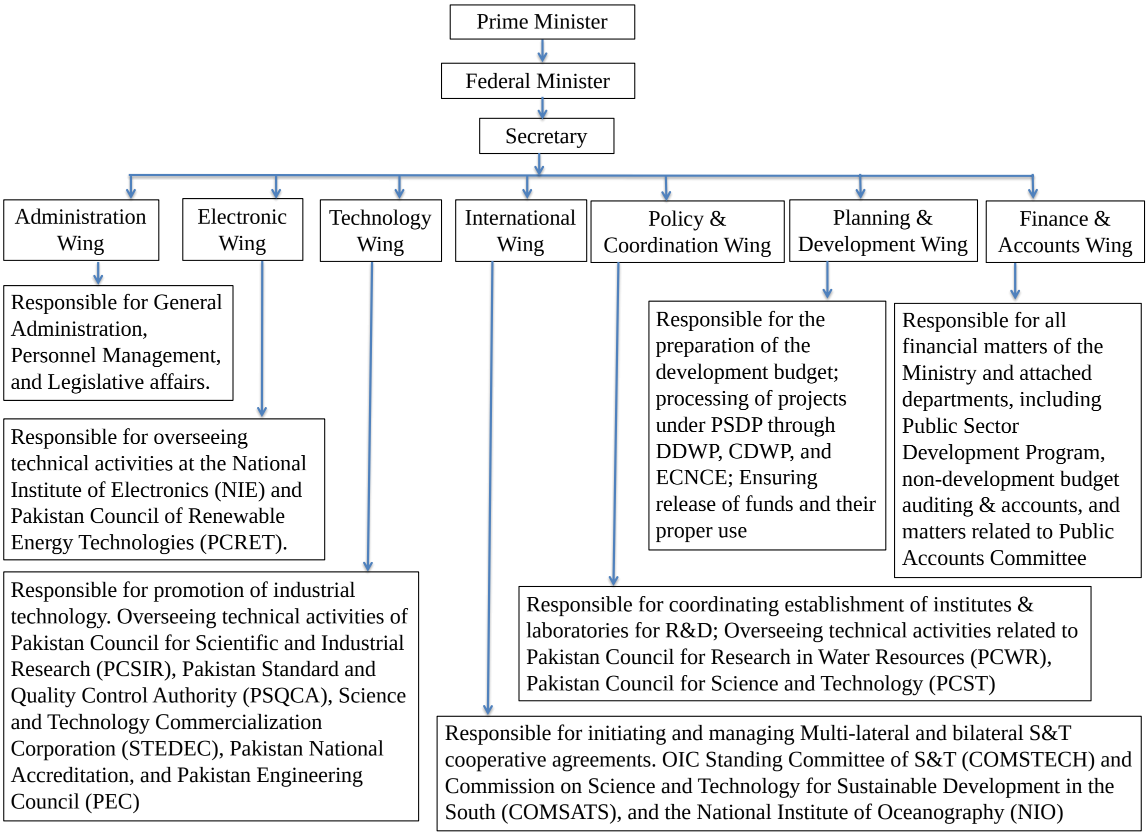

Fig. 1: Current organization structure of MoST.

6. Reorganization Strategy

Reform of institutions and enterprises is essentially a political process, which needs attention and careful nurturing spanning multiple administrations before it can take hold. Political consensus, transparency and accountability are vital to its success. Effective S&T reform requires coordinated action on three fronts: an articulation of a collective national vision, ensuring decentralized execution through effective leadership and institutional excellence, and the ability to form and sustain strategic partnerships.

6.1 Collective Vision

The scale and complexity of the S&T enterprise require a central planning and coordinating authority that has the mandate, credibility, and the expertise to not only manage the reform process, but to ensure its full implementation through weaving it within the national development strategy that has support of key stakeholders, including business and civil society. The government should consider promulgating legislation to establish a constitutional office of Chief Scientist of Pakistan. As a member of the National Security Council (NSC), the individual who holds this title will ensure that the national vision for scientific and academic excellence is developed through a transparent and deliberative process, is well-articulated, adequately funded and effectively executed by the government. The PCP will be the logical choice for managing the reform process, with MoST serving as an implementation partner. PCP led the development of Vision 2025 and is coordinating and ensuring projects under the China Pakistan Economic Corridor (CPEC), it is also responsible for developing the 12th five-year plan. The PCP and MoST must make every effort to ensure the workforce is fully engaged in the planning process. Only then will they assume ownership of the plan and the motivation necessary to ensure its effective execution. Because planning is an inherently uncertain undertaking, the Planning Commission must ensure that the formulated plans have enough flexibility to withstand unforeseen changes in geopolitics, the global economy, and/or advances in technology.

6.2 Decentralized Execution Through Effective Leadership and Institutional Excellence

The fulcrum of Pakistan's S&T enterprise is MoST. The activities of the Ministry can be classified into four broad categories: i) development of the national S&T investment strategy, ii) support of basic and applied research, as well as technology development in pursuit of national goals, iii) ensure provision of reliable science, engineering, research and analytical services to public and public-sector enterprises and iv) establish standards for scientific equipment, facilities, services and monitor compliance. The current organizational structure (Fig. 1) does not adequately reflect the nature of MoST as a demand-driven public-sector organization, whose customers include decision makers, government departments, private sector entities and the public at large.

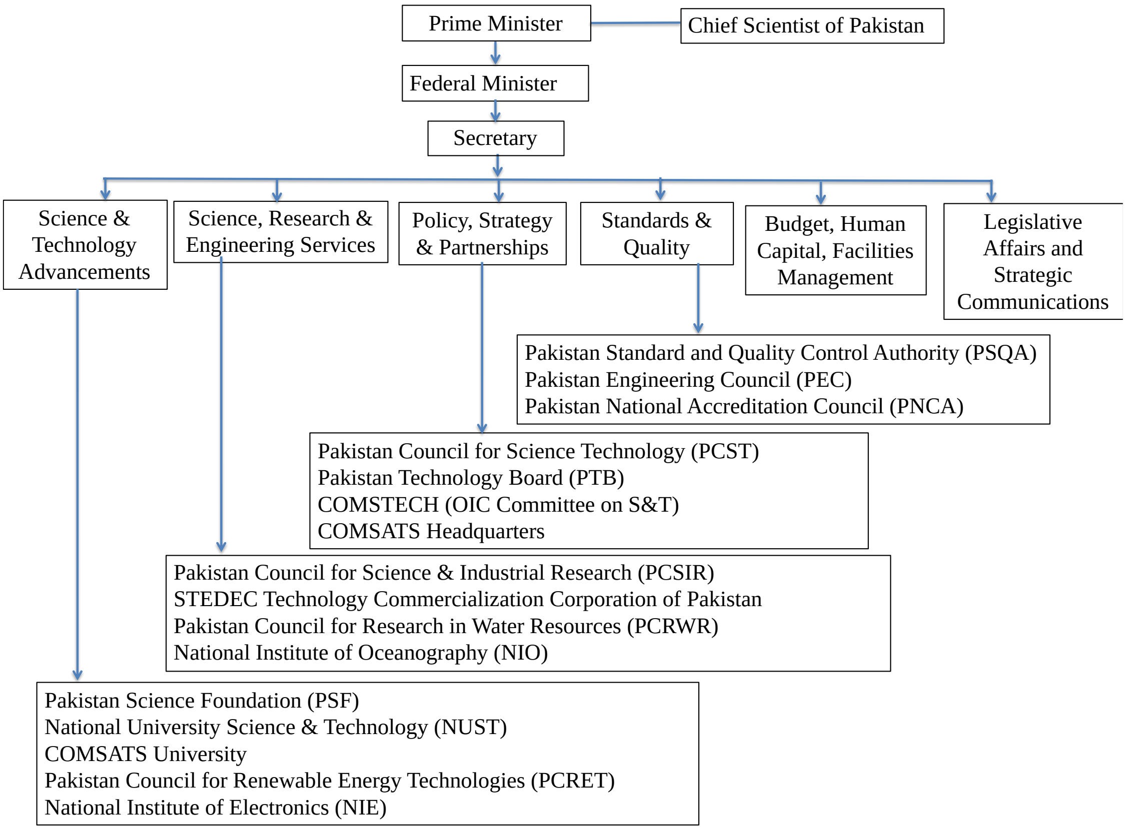

Fig. 2: Proposed organizational structure of MoST.

The most obvious approach would be for the government to reorganize the ministry and the subordinate departments along the above-mentioned categories (Fig. 2). It will provide an opportunity for subordinate departments and executive agencies to take a fresh look at the resources, facilities, talent, programs and processes that they have access to and what they might need in order to fulfill their mission. Human resource needs identified during this process will serve as a guide for Planning and Higher Education Commission as they attempt to align public investments in higher education with societal needs.

It is necessary that the government departments make a genuine effort to solicit input from potential customers and stakeholders regarding their needs, and what actions MoST could take to improve the quality of service that it provides. In time, the reorganization effort centered on MoST will produce a more integrated and coherent S&T investment strategy with specific goals, objectives, outcomes and metrics of success, all critical to program evaluation and accountability.

It is also important for government leaders to recognize that while information technology enables individuals and institutions to exchange information more efficiently, meaningful collaboration aimed at addressing complex challenges requires a particular set of values, culture and norms of behavior that must be cultivated and incentivized by heads of institutions. Clarity of goals, autonomy and accountability - issues that are critical to institutional health must be addressed promptly and in a transparent manner. The ministry, in partnership with subordinate departments must develop mechanisms that ensure selection of capable leadership, which in turn, must develop effective and transparent performance management systems that focus on nurturing mid-level managers throughout the enterprise and ensuring that excellence is rewarded.

6.3 Partnerships

Increased public sector investment in S&T is intended in part to increase the competitiveness of the private sector and encourage investments that generate employment opportunities. An understanding of the needs and challenges of the private sector and mechanism for cross-pollination of ideas is therefore critically important. Workforce mobility programs, like the one conceived and managed by the US Office of Personnel Management under the Inter-governmental Personnel Act (IPA) (5 CFR part 334, effective May 29, 1997) can serve to bridge the understanding between public and private sector organizations. The Act provides temporary assignment of skilled personnel across government, academia and private sector and is an effective means of facilitating cooperation between Federal Government and non-federal entities.

Finally, the globalization of S&T and competition for talent necessitates scientific and technical collaboration with friendly nations. The worldwide network through which researchers connect is critical to the long-term health of the institutions for which they work, and for the S&T enterprise as a whole. The Ministry of Foreign Affairs in partnership with the MoST must develop S&T engagement strategy aimed at achieving specific outcomes. Again, the strategy must be built around specific need that is identified through an open, transparent stakeholder engagement process.

7. Conclusions

Changes in climate, natural disasters and high levels of environmental pollution are likely to aggravate the governance challenge in developing countries. Failure to ensure delivery of essential services weakens the State and emboldens extremist groups as they search to establish influence and control over people and territory.

The ability of a modern society to fully exploit advancements in S&T is critical to its long-term prosperity and requires a shift from opinion-based policy making that is driven by ideology, prejudices, or conjecture to a more systematic approach which places the best available evidence at the heart of policy development and implementation process. A transparent decision-making process and demand for knowledge and insight creates the necessary pull on public sector research organizations, academia, and the private sector, which then have an incentive to invest in technology, personnel, and partnerships that allow them to satisfy the needs of their potential customers. The resulting competition and/or collaboration leads to the emergence of an ecosystem that is capable of addressing the evolving needs of a society.

While public investments in S&T throughout the developing world are abysmally low, what is more disturbing is the ineffective use of scarce resources. In this paper, the author examines the history, context, and evolution of the US and Pakistani scientific enterprise with the aim of gaining a more nuanced understanding of approaches and policies that have led to success. Consistent political support across multiple administrations, defense and national security needs, exceptional leadership, autonomous, transparent and accountable institutions and effective partnerships were the keys to success.

The author believes that Pakistan's social and geopolitical challenges demand that the federal government initiate a systematic effort to reorganize Pakistan's S&T enterprise. The scale and complexity of the S&T enterprise require a central planning and coordinating authority that has the mandate, credibility and the expertise to manage the reform process and ensure implementation. The Planning Commission is ideally placed to play that role, with MoST serving as the implementing agency. The ministry's current organizational structure does not adequately reflect its nature as a demand-driven public-sector organization, whose customers include decision makers, government departments, private sector entities and the public at large. The government must consider reorganization of the ministry aimed at better alignment with its core activities. It will provide an opportunity for subordinate departments and executive agencies to take a fresh look at the resources, facilities, talent, programs and processes that they have access to and what they might need in order to fulfill their mission. The government departments must make a genuine effort to solicit input from potential customers and stakeholders regarding their needs and what actions MoST could take to improve the quality of service that it provides. Human resource needs identified during this process will serve as a guide for the Planning and Higher Education Commission as they attempt to align public investments in higher education with societal needs. In time, the reorganization effort centered on MoST will produce a more integrated and coherent S&T investment strategy with specific goals, objectives, outcomes and metrics of success, all critical to program evaluation and accountability.

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