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Sannia Abdullah
Stanford University, sannia.abdullah@edu.edu

Pakistan's Space Program: From Sounding Rockets to Satellite Setbacks

Dr. Sannia Abdullah*

Why did Pakistan struggle for 50 years to launch its satellites into Earth's orbit when it was Asia's third country to send sounding rockets into space? Four years ago, India launched 104 satellites from a single rocket to set a groundbreaking record,[1] whereas Pakistan launched only six satellites with assistance in the design, built, launch, and even funding from China.[2] Pakistan plans to send its first astronaut into space by 2022;[3] India put its first astronaut into "space in 1984 as part of a Soviet-led mission."[4] Despite a good head-start, why is Pakistan's space program decades behind when India's space expedition started eight years later? The literature on Pakistan's space program suggests that the country's staggering space performance is because SUPARCO (Pakistan's national space agency) was "denied the funding and resources needed to ensure a sustained rate of advancement and innovation."[5] Some scholars argue that the commission was neglected because of "bureaucratic hurdles, and mismanagement,"[6] while others believe that "the political turmoil which enveloped the country"[7] for decades caused inadvertent delays. However, the fundamental reason behind Pakistan's inadequate space performance in Asia's space race is the lack of technical expertise to harness indigenous space capabilities. The commission over the years relied on a handful of foreign-trained scientists and engineers, imported technology for quick fixes, and used foreign launch facilities to keep its head above water. These temporary arrangements rang the nonproliferation bells, and in 1991 SUPARCO faced"technological denial"[8] from the West under sanctions. As a result, the satellites missed deadlines to join the designated orbital slots. This added a financial burden to the debt-trap economy of the country, and the vicious circle was hard to break for decades. After the 1998 nuclear tests and the subsequent military coup (8 October, 1999), SUPARCO among other strategic organizations came under the umbrella institution of the Strategic Plans Division (SPD). Since then, it has been operating under military officers, unlike India's ISRO, which is guided by scientists who lead the agency with task-oriented missions. To spearhead the space-race against India, SUPARCO is circumventing the natural learning curve of research and development under military leadership that observes strict hierarchy within the commission. Seniority supersedes talent, thus making the institution a less attractive career choice for young graduates. This paper address three important questions: First, what are the factors behind SUPARCO's snail's pace? Second, why does Pakistan not have a satellite launch vehicle (SLV), needed to launch satellites into Earth's orbit, when it has already mastered the ballistic missile program? Both SLV and ballistic missiles are very similar technologies. Third, what measures can improve Pakistan's space program?

The Space Flight and Path of Technology Import

SUPARCO was founded in the space age, when the Soviet Union shocked the world with the successful launch of the first artificial Earth satellite (Sputnik-1) on 4 October, 1957. The United States, triggered by space developments, started the Apollo mission to make the first human landing on the moon. To accomplish the mission, the U.S. space agency - National Aeronautics and Space Administration (NASA) - needed necessary information on the wind structure of the upper atmosphere and sought cooperation with Indian Ocean littoral states for establishing rocket ranges to collect data. This opportunity brought two space agencies, NASA and SUPARCO, closer. Prof. Abdus Salam[9] (the Pakistani Nobel laureate) and his team[10] met NASA officials and seized the offer. In June 1962, the United States launched two U.S. rocket motors, the Nike and the Cajun, from Sonmiani Beach (Karachi-Pakistan). The rocket reached an altitude of almost 130 kilometers. NASA hailed the launch as the beginning of a program of continuing cooperation in space research of mutual interest."[11] Just a few days later, on 7 and 11 June, 1962, Pakistan launched two sounding rockets, Rehbar-I and Rehbar-II, using NASA's launch facility at Somniani, thus making Pakistan Asia's third country for shooting rockets in space.[12] Even though Pakistan's development of two-stage solid-fuel rockets marked a huge achievement of the time, it is not a coincidence that Rehbars are technologically identical to NASA's Nike-Cajun/Nike-Apache rockets. Both rockets not only look similar but carried almost the same payload of 80 pounds and reached the same altitude of 130 kilometers in the atmosphere, like Nike-Cajun/Nike-Apache. It is fair to assume that Rehbars are Nike-Cajun/Apache. The systems have the same length and diameter (See Figures 1A and 1B). The evidence further suggests that Rehbars provided Pakistani scientists with the same information on wind shear and layers of the upper atmosphere outside the stratosphere[13] as was needed for the Apollo mission. SUPARCO's official website admits that "Rehbar-I consisting of a Nike-Cajun combination (which was earlier developed by NASA) was successfully launched from Sonmiani Rocket Range."[14] Thus, the "honor of becoming the third country in Asia and the tenth in the world to conduct such a launching"[15] was not a feather in SUPARCO's cap.

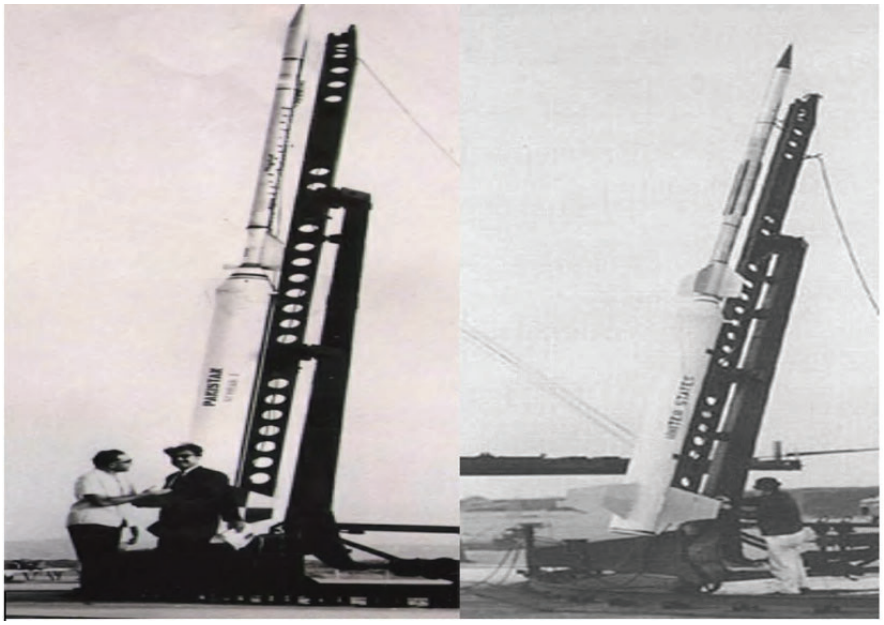

Image 1A (Rehbar-1) **Image 1B (Nike-Cajun)**

Source: Image 1A shared by @AwaisBajwa; Image1B at https://history.nasa.gov/SP-4402/ch5.htm

After launching the sounding rockets, the path for short-range ballistic missiles would have been much easier; however, SUPARCO faced several hurdles in developing short-range systems. The Hatf missiles did not come into public awareness until 6 February, 1989,when Pakistan's then Army Chief Gen. Mirza Aslam Beg at National Defence College announced the development of "Two indigenously manufactured surface-to-surface missiles Hatf-1 and Hatf-2," and also asserted that the "guidance system used in missiles [was] extremely accurate and developed in Pakistan."[16] Hatf was a surface-to-surface short-range system with "no in-flight guidance as evidenced by the long launch ramp that accompanies it."[17] It could "theoretically carry a tactical nuclear weapon", although Pakistan declared it non-nuclear.[18] Pakistan claimed Hatf systems were "indigenous" and a modification of French-sounding rockets, the single-stage Dauphin or two-stage Eridan.[19] Some experts who believe that Hatfs are Chinese systems are not wrong. Pakistan's then foreign minister, Abdul Sattar, on 26 August, 1993, stated in the Pakistan Senate, "These missiles [HATF] were bought keeping in mind Pakistan's security needs."[20] Some U.S. officials questioned the accuracy of Hatf-1 and Hatf -2 systems and claimed, "The Hatf-1 is an inaccurate battlefield rocket that can fly 80 kilometers…the Hatf-2 is just two Hatf-1s put together."[21] The flight range of 300 kilometers was exaggerated and "Neither missile is a very high-tech product."[22] The status of Hatf-1 and 2 systems remained unclear on serial production and deployment in public knowledge. In 1995, the Hatf-1A replaced the Haft-1 and

Hatf-1B replaced Hatf-2 in 2001 with an improved range (~80 kilometers) and accuracy. The need for improved versions validates the U.S. officials' claims that Hatfs were not as stable and efficient systems as projected by Pakistani authorities. In 2011, Pakistan tested another short-range/battlefield surface-to-surface ballistic missile, Nasr (Hatf-IX -60-kilometer range).[23] Nasr is a nuclear-deliverable solid fuel, single-stage rocket developed by National Defense Complex and already inducted by the Pakistan army. If Hatfs were efficient systems, Pakistan's missile inventory wouldn't need another short-range system like Nasr. Apart from Hatf-1 and 2, Pakistan's track record with other Hatf systems around that time was not satisfactory either. In the mid-1990s, A.Q. Khan (head of KRL) traveled 13 times to North Korea to "receive technical assistance for the development of the Ghauri missile, an adaptation of the North Korean No Dong design."[24] The initial test of the Ghauri missile failed, and the debris fell into Iran because the nose cone burned upon re-entry because of hypersonic effects and high-temperature shifts. The new system had to replace the engine and propellent, and the nose cone had to redesigned.

The Satellite Setbacks

Since the beginning, SUPARCO has faced technological setbacks in manufacturing satellites and launching them into Earth's orbit. In 1992, after the success of the Badr-1[25] satellite, SUPARCO concentrated its efforts on Badr-B, a cube-shaped Earth observation satellite made of "space-qualified aluminum T-6 alloy,"[26] equipped with "several CCD cameras, compact dosimeter, a telemetry system, charge detector, and a temperature control unit."[27] The CCD camera is a sophisticated technology used for remote sensing.[28] Pakistan contacted Rutherford Appleton Laboratory (RAL) for assistance in CCD cameras.[29] The satellite completion took longer than its due date, leading Pakistan to miss its orbital entry slot for the planned launch in 1994. The commission contacted China and Russia for the lowest rates of launch. The cooperation with Russia further delayed the launch by four years, frustrating the scientific community in Pakistan. After missing four chances, SUPARCO launched communication satellites to keep the geostationary orbital slot in space.[30]

Until now, SUPARCO has indigenously built only two experimental satellites, the Badr-1 and PakTES-1A. The PakSAT-1R and PRSS-1 were made in China and sold to Pakistan. In December 2001, Pakistan leased the US HG3, "Originally launched as Indonesia's Palapa C1 and later sold to Turkey [Anatolia 1] - and renamed it PakSAT-1."[31] Pakistan moved this satellite from Turkey's orbital slot to Pakistan's slot.[32] It was a geosynchronous and communication satellite built by the Boeing Company (Hughes).[33] Around 2004, scientists planned to launch the satellite using a Shaheen-III booster from an unknown facility in Pakistan. However, in October 2008, Pakistan contacted China to buy Chinese satellite PakSAT-1R and sought launch service and a platform. Pakistan's economy was so weak that China provided Pakistan a soft loan of 1.35 billion RMB (around US$200 million), with a maturity

period of 20 years for the satellite. On 11 August, 2011, PakSAT-1R was launched from China and replaced PakSAT-1. After seven years, (9 July, 2018), Pakistan launched its two remote sensing satellites, PRSS-1 and PakTES-1A, from China's Jiuquan Satellite Launch Center using Long March-2C rocket.[34] PRSS-1 is an optical remote sensing and Earth observational satellite, again purchased from China,[35] and is part of Sino-Pak space cooperation that will enhance cooperation in climate change, disaster management, risk reduction, and other areas of mutual interest.[36] However, because satellites are dual-use systems, the military implications are ripe for speculation. PRSS-1 has spatial resolutions as fine as 1 meter in panchromatic mode and 4 meters in multispectral mode. Such features characterize "high geometric precision, short revisit intervals, and rapid data supply. Such imagery will provide greater spatial details on the land surface and open new applications relevant to social sciences."[37] China's stated aim of the PRSS-1 is to monitor the progress of the China-Pakistan Economic Corridor (CPEC) project in Pakistan. The satellite's sophisticated technology will "carry out day and night monitoring, and it has viewing capacity even in clouded conditions."[38] The other satellite, PakTES-1A, indigenously built by SUPARCO engineers, was co-launched with PRSS-1.[39] The table below outlines the details of Pakistani satellites type, features, life span, launching facility, and launch locations.

Satellite Name	*Launch/Entry into Orbit Date*	*Location*	*Launcher*	*Satellite Type*	*Built/Manufactured*	*Life Span*
Badr-1 *150KG*	July 16, 1990	Xi Chang Station (China)	Long March 2E Rocket	Experimental Artificial satellite	Jointly built by SUPARCO and CNSA	One month
Badr-B *68KG/ALT:986 KM*	December 10, 2001	Baikonur Cosmodrome-Kazakhstan	Zenit-2 Rocket	Earth observational Satellite	UK- Space Innovations Limited & Rutherford Appleton Labs	2 years
PakSAT-1 *3000KG/ALT:35,400KM*	December 20, 2002.	Moved from previous orbit to Pakistan's orbital slot	—	Geosynchronous Communication Satellite	The Boeing Company Leased by Pakistan from US Hughes	~10 years
PakSAT-1R *5200KG/ATL: 35,700KM*	August 11, 2011	Xi Chang Station (China)	Long March 3B	Geosynchronous, Communication Satellite	Great Wall Industry Corporation (China)	12-15 years
PRSS-1 *1200KG/ATL: 640KM*	July 09, 2018	China's Jiuquan Satellite Launch Center (China)	Long March 2C Rocket	Optical Remote Sensing & Earth Observational Satellite	China Academy of Space Technology (CAST) - Sold to Pakistan	6-8 years
PakTES-1A *300KG/ALT: 610KM*	July 09, 2018	China's Jiuquan Satellite	Long March 2C Rocket	Experimental Satellite	Built by SUPARCO	—

Source: Data collected by the author from different sources

Quest for a Satellite Launch Vehicle (SLV)

For years, SUPARCO has used China's expertise and launch facilities for its satellites."Pakistan is currently on the list of those countries which lack launching facility."[40] Most of the payloads are launched in space using expendable launch vehicles (ELV).[41] ELVs are relatively less costly because they use disposable components for the launch and hence, they are not reusable. In 1999, SUPARCO's former chairman announced that "Pakistan would develop its satellite launching vehicle within a period of about three years."[42] So why could Pakistan not develop its SLV? Shahid Qureshi, head of the Institute of Space and Planetary Astrophysics, also wondered, "If we can launch a [IRBM] missile up to a range of 1,500km, why not build an SLV that can launch low-atmosphere satellites?"[43] However, many within SUPARCO believe"SLVs involve complex technology and are beyond what Pakistan can do on its own."[44] As per the latest public information, "Pakistan has already completed three of the four stages of its SLV."[45]

The commission has long been trying to develop a low-cost rocket booster[46] to launch lightweight satellites into low-Earth orbits (LEO). In the early 2000s, Pakistan started a design study on two SLVs presented in the IDEAS 2002 defense exhibition. The first design points to the three-stage model of SLV having a"lengthened common core booster without the strap on" and the other design uses "four strap-on boosters attached to the common core."[47] Both designs were higher modifications of Shaheen-I/M11 and Shaheen-II/M-18 systems with an upgrading and changes in solid motors to increase the thrust of the booster of Shaheen systems.[48] Instead of SLV, these designs led to the development of the Shaheen-III multi-stage solid-fuel surface-to-surface ballistic missile, test-fired on 9 March, 2015, having a 2,750-kilometer range[49] and jointly designed by NESCOM and SUPARCO. Shaheen-III's test showed a strike role to cover the strategic targets of the Nicobar and Andaman islands in the Indian Ocean, coming in response to India's Agni III.[50] The hindsight purpose of Shaheen-III, however, was the gradual upgrading of Shaheen systems using existing expertise and hardware towards the development of a satellite launch vehicle. Two years later (24 January, 2017), Pakistan tested, Ababeel, a surface-to-surface medium-range ballistic missile capable of carrying multiple payloads. It is a multiple independently targetable reentry vehicle (MIRV).[51] As seen in Image 2, Ababeel is an improved version of the Shaheen-III system, with a third stage added. Pakistan's Ababeel has significant

similarities to the Chinese KuaiZhou KZ-1A system, except KZ-1A is a "four-stage rocket, using solid rocket engines on the first-, second-, and third-stage, and a liquid fourth-stage which is also the payload."[52] The nose cone ofAbabeel is bigger than that of Shaheen-III and is designed for multiple payloads. Ababeel could probably be used for space launch to transport multiple payloads into space at one time, just as India did. Taimoor, as shown in the Image 2, could be an ICBM still in the manufacturing phase.

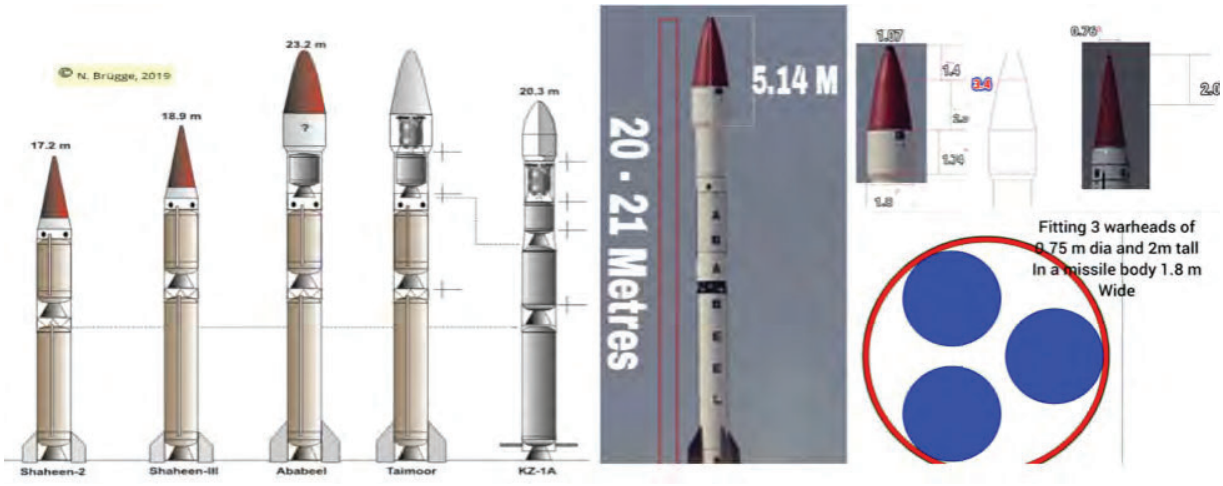

Image 2
Source:http://www.b14643.de/Spacerockets_1/Rest_World/Taimoor/Versions/Taimoor.jpg

Ababeel will be transported through a transporter erector launcher (TEL) vehicle to the launch site within hours, instead of weeks of preparation. Pakistan's national parade images reveal Shaheen-III on TEL, which is longer to accommodate the missile. The image below shows that this TEL is for a bigger system like Ababeel. Now when the need for the satellite launch vehicle seems to have been resolved, there are several other challenges for SUPARCO to advance the country's space program.

Image 3

Source: Image from Inter Services Public Relations (ISPR) - Pakistan

Insufficient Space Knowledge and Expertise

The need for foreign assistance in satellite developments is Pakistan's dearth of trained professionals and weak economy as presented by the Pakistan Aqkan situation. The scientific education program requires special attention, particularly in the disciplines of applied sciences and space studies. There are only a handful of universities "offering aeronautical engineering degrees and there are yet fewer institutes committed to scientific research and development."[53] SUPARCO is currently hiring graduates from two major institutions, the Institute of Space Technology (IST) and the National University of Sciences and Technology (NUST). The IST offers engineering in space sciences, electrical, mechanical, material sciences, avionics, aerospace, and satellite engineering. Some Ph.D. programs operate in collaboration with Chinese universities.[54] NUST offers aerospace engineering, avionics, and aeronautical engineering. Interestingly, within the space research lab of NUST, most of the faculty received training from the Pakistan Air Force Academy at Risalpur.[55] Other educational institutions include Air University, Karachi University, and the University of Punjab. Karachi University offers graduation in Space Science and Technology and has a long association with SUPARCO. The University of Punjab has departments of metallurgy and materials engineering, electrical, and polymer engineering and technology with a focus on emerging technologies. Some faculty members are foreign qualified with Ph.D.s from the UK, New Zealand, and Australia.[56] The Air University offers a bachelor's degree and Ph.D. in electrical, mechanical, mechatronics, avionics, and aerospace engineering. Pakistan has only one university in the country that currently offers a Masters in Applied and

Computational Mathematics; however, no university is offering education on optical physics. SUPARCO's former chairman, Maj. Gen. Ahmed Bilal, also mentioned that "At a base level, two major disciplines in HR are lacking in Pakistan: i) Applied Mathematics, ii) Optical Physics."[57]

Instead of creating universities to improve scientific education, Pakistan has been relying on foreign training programs/scholarships. In the early 1960s, the NASA-SUPARCO cooperation agreement trained Pakistani scientists and technicians at NASA space science centers. This practice continued and Pakistan sent over 500 scientists to the United States.[58] Most of them returned home to work for Pakistan's nuclear and missile program. The second generation of scientists received training in the 1980s when SUPARCO sent hundreds of engineers to the University of Surrey (England) in the development of UO-11, launched in 1984. From the year 2000 onwards,"A very large number of young engineers and scientists were sent to foreign universities in the USA, the UK, France, the Netherlands, Germany, Sweden, China, and South Korea under the HEC-funded programs and from SUPARCO's budget."[59] The commission also seeks cooperation with other space organizations such as the Office of Outer Space Affairs of UNO in Vienna, Asia-Pacific Space Cooperation Organization, Inter-Islamic Network on Space Science and Technology for training. It's not publicly known how many engineers/scientists return home after completing the training programs. Air Cdr. Arshad Siraj mentioned to the author that there were many returning scholars in the beginning, but they tapered off in the following years.[60] Pakistan's current government expedited some initiatives to prioritize the space program. In 2018, four major centers of excellence were created to augment space and allied sciences programs. These include the National Centre of Artificial Intelligence[61], the National Centre of Robotics and Automation[62], the National Centre for Cyber Security, and the National Centre of Big Data and Cloud Computing. These institutions are formed with "the mission of accelerating technological development through scaling up the availability of the scientific community to advance the national space and allied science programs."[63] Apart from technical education, SUPARCO needs high-quality research to apply knowledge to create a product line that requires separate resource allocation in the national budget.

Economic Challenges

Pakistan's weak economic base delays SUPARCO's performance output. Pakistan has a "semi-industrialized economy that relies on manufacturing, agriculture, and remittances."[64] As of July 2019, Pakistan's GDP is 5.79%, which is not good for the fast-growing population. According to the World Bank, Pakistan's current account deficit (CAD) in FY 2018 reached 6.1 from 4.1 of FY 2017.[65] The economic trends of this year are more worrisome with the growth rate declining from 6.1% to 3.3% in FY 2019 and is likely to go down to 2.4% by next year.[66] Pakistan signed another

bailout package with the International Monetary Fund (IMF) of $6 billion. As of FY 2018-2019, the country's defense budget makes up a fifth of the government's total spending, estimated to be around $8.5 billion.[67] Given the current "critical financial situation", the Pakistan military froze its defense budget, calling it "a voluntary cut."[68] However, despite this arrangement, "the federal government hand over more than half its budget to the provinces and the rest is mostly eaten up by debt servicing and the military's vast budget."[69] The current economic outlook poses more serious challenges to the space program even though the government promised that "SUPARCO will receive a budget of just more than $40 million for fiscal 2018-2019."[70] The debt has already ballooned over "Rs33 trillion, and an ambitious space program will likely pop this balloon."[71] Despite functional prototypes, Pakistan does not have the technology for satellites because of the associated expense. The next thought is whether China would help Pakistan.

On 29 April, 2019, Pakistan and China signed a space agreement aiming to "conduct scientific and technological experiments, astronaut training, along with manned space applications and achievement transformation."[72] The federal minister for Science and Technology, Fawad Chaudhry, said, "China is Pakistan's natural entryway into space…"[73] But there are concerns about space ambitions. For instance, according to the Pentagon,"China's satellite launches are ominous."[74] China's military"continues to strengthen its military space capabilities despite its public stance against the militarization of space" including the BeiDou navigation system and new weaponry.[75] Although seen suspiciously in the West," China and Pakistan have enjoyed over 20 years of cooperation in Space Science, Technology and Applications."[76] China's space competition with the United States and India will benefit Pakistan in expediting its space endeavors as China is the best bet for Pakistan, which will share technology on soft loans. The greatest challenge here is the nonproliferation regime.

The MTCR and Space Cooperation

Under the Missile Technology Control Regime (MTCR), transferring missile-related technology hardware or knowledge or component that contributes to the development of missiles capable of carrying 500 kilograms of a payload a distance of 300 kilometers or more is strictly forbidden. Pakistan and China are not members of MTCR. Although China applied for membership in 2004, the members shared concerns about China's past export control policies, particularly regarding technology transfers to Pakistan and Saudi Arabia. Pakistan has not applied for MTCR membership yet. The catch for non-members is that ultimately the non-nuclear weapons states will have to give up their ballistic missiles capable of carrying a payload of 500 kilograms over 300 kilometers or more. Pakistan is not alone in benefitting from overseas' help with technology; India's space agency (ISRO) received missile technology, including "several cryogenic upper stages along

with the production technology," from Russia, while U.S. satellite transfers to China in 1993 later raised proliferation concerns.[77] SUPARCO became victim to non-proliferation sanctions for technology reliance. These sanctions time to time affected SUPARCO's performance. For instance, in June 1991 the Bush administration levied missile sanctions on SUPARCO under the Arms Export Controls Act and the Export Administration Act of 1979.[78] In 1994, China agreed to facilitate Pakistan in providing soft technology and develop the infrastructure for the ballistic missile program for Ghauri missiles. North Korea shared the hardware components (of Nodong and Taepodong missile systems) and helped to transfer Chinese technology through North Korea to Pakistan."China is believed to have agreed to supply components like the guidance systems, the areas in which North Korea does not have sufficient technological capability."[79] Apart from China and North Korea, some European countries also facilitated Pakistan in the early stages of rocket development. Like "France transferred technology to manufacture sounding rockets and German firms assisted in space research and supplied several tons of ammonium perchlorate, an ingredient of solid rocket fuel. The UK also helped with sounding rocket launches."[80] In 1995, the United States cautioned European countries on supplying missile-production equipment to SUPARCO.

Because of these restrictions, SUPARCO contacted its Asian partners. However, it did not turn out well as Taiwan (March 1996) confiscated shipments of around 15 tons of ammonium perchlorate for SUPARCO, shipped from North Korea.[81] Just one month later, another shipment of ammonium perchlorate in a quantity to fuel nearly 25 missiles was seized by Hong Kong customs .[82] Of course, SUPARCO denied the shipments. In 1998, SUPARCO came under sanctions again for "unspecified involvement" in nuclear and missile technology. Thus, under section 102(b) of the Arms Export Control Act of the United States, the Bureau of Export Administration imposed more sanctions against India and Pakistan for denying their licensing of exports of items restricted under nuclear nonproliferation and missile technology.[83] In 2001, President George W. Bush lifted the 1991 and 1998 sanctions by exercising waiver authority granted by Congress.[84] The new era of China-Pakistan space cooperation further tests the validity of MTCR in present times. According to the South China Morning Post, Pakistan had bought a highly sophisticated, large-scale optical tracking and measurement system that is critical for missile testing from China .[85] Pakistan is the first country with whom China shared the application of BeiDou navigation - a parallel system against the US GPS for commercial and military use.[86] As"BeiDou boosts the capabilities of the People's Liberation Army in areas including weapons targeting, guidance, and other services,"[87] it reduces China and Pakistan's reliance and vulnerability to future sanctions from the West.

What Can be Done?

Now when Pakistan's government is prioritizing the country's space program, some measures need immediate attention for wider implications. First, Pakistan requires a strong scientific education base particularly in STEM (Science, Technology, Engineering, and Mathematics) discipline. Pakistan's education system is already in a crippling phase. The ad hoc policy of scholarships for training scientists and engineers is not a solution for developing a firm base for the space program. The current human resource comes from limited programs offering space studies/diplomas that lead to SUPARCO's institutional inbreeding. The government of Pakistan must reform education policies with greater emphasis on applied sciences. Because Pakistan's need for commercial satellites is rising every year, public demand for internet users is increasing. As of 2020, there are 76.38 million internet users in Pakistan, of which around 37 million use social media. For increasing greater awareness and interest in the national space agency, the rural population needs access to education and the internet.

Second, SUPARCO, like several other space agencies of the world, needs civilian oversight to yield research and development and create a better work environment. Like other countries, SUPARCO needs to give contracts to government-owned, but not government-managed, companies. It needs to promote merit over seniority and reward young scientists/engineers to work and compete for their research projects to enhance innovation and promote ideas. The agency operating under military leadership is a less attractive workplace for young graduates. From independent reviews of the SUPARCO employees (former and current), only 53% recommend the organization for the job to newcomers and not one reviewer approves of the CEO of the organization, the chairman.[88] Out of 22 reviews, 31% of reviews do not recommend the organization for the job. Employees' reviews also suggested that the"chairman should be within the organization and have at least relevant background to run the National Space Agency."[89] The usual complaints are "no career progress…, no respect for staff officials…office etiquette is more important than productivity and timeliness."[90] Some mentioned that "the talent gets rusted here, no appreciation for hard work"[91] while others complained about the behavior of senior management saying that "the immediate superior always suppress your complaint/request/application."[92] One reviewer said,"qualification and performance are not given very healthy weight. Rather, the seniority matters the most."[93] "Remove the element of fear from within your employees. This will enhance their output," "Reduce procedures and encourage research work more."[94] These comments show dissatisfaction among employees who currently work or already left. Former chairperson SUPARCO also confirmed that "The National Command Authority just has a different work ethic. There are stringent requirements for both recruitment and performance."[95]

Third, SUPARCO's institutional identity seems compromised and the institution's new role is unclear? The limited scope of focusing entirely on space satellites is not enough. SUPARCO's 2040 space vision allocated $22 million for the multi-mission program for launching five GEO and six LEO (low Earth orbit) satellites into space in cooperation with China. Apart from satellites, the missile production-related work is already given to other strategic organizations such as National Defense Complex (NDC), Air Weapons Complex (AWC), Defense Science and Technology Organization (DESTO), Pakistan Atomic Energy Commission (PAEC), and Pakistan Ordnance Factories (POF). It seems that SUPARCO provides the auxiliary support to buttress the nuclear program of the country instead of having an independent mission. One of the former chairmen said, "We do a lot of gratis work for the government…By Sept 1, 2010, we had done about $4 million worth of gratis work."[96] To keep its identity, SUPARCO needs to widen its expertise through a public-private partnership, create awareness of science and development at universities/schools to create human resource pool, and develop a competitive market for research and development in space exploration to reward youngsters to join the commission.

Conclusion

Pakistan's space program lags behind other Asian powers due to a lack of professional expertise in space sciences and applied studies. The commission never had the expertise for developing 'indigenous' missiles or satellites. The sounding rockets (Rahber-1 and 2) were Nike-Cajun rockets from NASA. From Ghauri systems to Shaheens, Pakistan has been taking assistance from Asian partners, particularly China, to develop its missile program. Instead of harnessing a strong education base for Science and Technology in the country, successive governments relied on makeshift arrangements of foreign training and technology assistance to complete projects. The research also concludes that Pakistan's Ababeel missile is a design for a satellite launch vehicle that the military tested in the missile role to deter India's ballistic missile program. The MIRVs test does not show the independent targeting capability of each warhead. The study also concludes that despite the government's ill-conceived space vision, SUPARCO as an organization faces serious challenges, particularly under military leadership. The slow pace of research and development, dissatisfaction among employees, and lack of incentive for young graduates to seek employment in the commission enunciate that the space agency needs dedicated mission and civilian oversight, as India has with ISRO. Pakistan-China space cooperation cannot give Pakistan a breakthrough against its regional competitor, India. The space expedition is costly. SUPARCO should benefit from the public-private partnership and invite private companies to invest in space exploration, taking inspiration from Elon Musk's SpaceX.

*Dr. Sannia Abdullah is affiliate at Center for International Security and International Cooperation

(CISAC), Stanford University, where she was a Stanton Nuclear Security Postdoctoral Fellow (2017-2018). This project was her research completed at Center for Monitoring Cooperation, Sandia National Labs (2019). The author extends her special thanks to Adriane Littlefield and Eric Wallace for their valuable research input throughout the project. Author extends her special thanks to Dr. Damon V. Coletta for his motivation to write on Pakistan's space program.

Notes

1. Among 104, three satellites were from India and other Nano-satellites were from five other countries including U.S., the Netherlands, Kazakhstan, Israel and Switzerland. For details see Samantha Mathewson,"India Launches Record-Breaking 104 Satellites on Single Rocket," February 15, 2017,https://www.space.com/35709-india-rocket-launches-record-104-satellites.html

2. Salman Siddiqui,"LaggingBehind: 2040 - Pakistan's Space Od[d]yssey,"*The Express Tribune*, August 01, 2012, https://tribune.com.pk/story/415738/lagging-behind-2040-pakistans-space-oddyssey/

3. Pakistan's incumbent Minister for Science and Technology tweeted @fawadchaudhary, July 25, 2019 at https://twitter.com/fawadchaudhry/status/1154293483504619520?lang=en

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