DEVELOPMENT OF AEROSPACE INDUSTRY IN CHINA AND BRAZIL

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INTRODUCTION

India's aerospace industry has often been compared unfavourably to that of other countries that were at the same level as India was in 1947, when as a newly independent Third World country, it embarked upon a process of modernisation and nation building. This comparison is most often made with the People's Republic of China (PRC) and Brazil. Therefore, it is pertinent to take a look at the development of the aerospace industry in these two countries in order to compare it with the industry's growth in India. The benefit of the brief examination of the aerospace industries in the PRC and Brazil lies in ascertaining the role played by international cooperation and innovation in the development of these foreign aerospace industries.

GENESIS OF AIRCRAFT INDUSTRY IN CHINA

The Chinese had experimented with manned flight in several periods of their long history. Experiments were carried out with kites large enough to be able to carry a man aloft for observation of the surrounding area from a military perspective.[1] These experiments were followed by experiments

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1. Joseph J. Cornish, III, "Go Fly a Kite", http://www.naturalhistorymag.com/htmlsite/master.html?http://www.naturalhistorymag.com/htmlsite/editors_pick/1957_04_pick.html. Accessed on April 13, 2016.

In the early years of the development of Chinese aviation, especially military aviation, the main source of assistance, guidance, advice, financial support, and equipment for the Chinese Air Force was the Soviet Union.

with manned hydrogen filled balloons and rudimentary autogyros. However, nothing much came of these experiments until the early 20th century. In the chaotic period towards the last years of the Qing Empire, in 1910, an aircraft factory was set up by the Qing government at Nanyuan. The first aircraft built here was tested in 1911 but failed, resulting in cessation of further activities aimed at modern aviation technology for the time being in China.[2]

Several warlords in China, in the early 20th century, fielded air assets in the form of 'squadrons' of about ten aircraft each.[3] The current day People's Liberation Army Air Force (PLAAF), the air force of the PRC, traces its origin to 1924.[4] Several aircraft repair facilities were set up at various Chinese locations such as Qinghe and Beijing in the early 20th century. During the time of the joint rule of China by the Chinese Nationalists and the Communist Party of China (CPC), an aviation bureau was established in 1924, at the Huangpu Military Academy. Out of the intake of 50 pupils in the first batch of pilot trainees at this training institution, 18 were sent to the Soviet Union for training. In the early years of the development of Chinese aviation, especially military aviation, the main source of assistance, guidance, advice, financial support, and equipment for the Chinese Air Force was the Soviet Union.[5] The Nationalist government undertook the establishment of a number of aircraft factories at Hanzhou, Shanghai, Nanjing and Wuchang in the early 1930s.[6] These factories were set up with the assistance of various foreign powers from Europe and the US. The Central Nanchan Aircraft Factory was established in the early 1930s,[7] in collaboration with the Italian firms

2. D. R. Mohanty, "The Dragon Flying High? Examining China's Aerospace Industry: The Maoist Era", *Strategic Analysis*, vol. 23, issue 12, 2000.
3. Xue Guangqiu, *War Wings: The United States and Chinese Military Aviation, 1929-1949* (London: Greenwood Press, 2001), pp. 30-36.
4. Mohanty, n.2.
5. Ibid.
6. Ibid.
7. Ibid.

and this factory was designed to produce aircraft under licence. The Shaoguan Aircraft Factory was established, in the early 1930s, in collaboration with Curtiss Aeroplane and Motor Company, later to become the Intercontinental Aircraft Corporation of the United States, and was also run jointly with the same American firm.[8] The Air Force No. 3 Aircraft Factory was established at Chengdu by the mid-1930s. Another factory was established by the mid-1930s, in the Guizhou province for the production of American origin aviation specific piston engines.[9]

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In 1930 and 1931, 43 American military aircraft worth $ 1 million were delivered to China[10]. In 1933, the American Curtiss Hawk fighter was demonstrated to the Chinese government. As a consequence, on indication of firm interest from the Chinese, the American Curtiss Airplane Company sent Mr. William Pawley to China for negotiating aircraft sales as well as setting up aircraft manufacturing factories in China. After protracted negotiations, Mr. Pawley signed a contract for the setting up of an aircraft factory at Hangzhou, at a cost of $ 250,000. The Chinese Nationalist government was to repay this amount in five years. The factory was ready in mid-1934 and after repairing ten Curtiss Hawk aircraft, went on to manufacture 127 Hawk fighters, at least initially from imported kits, over the next 30 months.[11] The Central Aircraft Factory at Hangzhou was manufacturing 30 Vultee dive bombers in July 1937, when war with Japan broke out. After being bombed and damaged by the Japanese, this factory was shifted to Loiwing, close to the Burma border. At this location, the factory initially continued to manufacture Hawk fighters and Vultee dive bombers, though with some difficulties due to the incomplete infrastructure, inhospitable climate, and poor lines

8. Ibid.
9. Ibid.
10. Guangqiu, n. 3, pp. 41-43.
11. Ibid., pp. 69-70.

of communication at the new location. These adverse factors led to the production rate at the new location of the factory staying very low. The factory was again bombed by the Japanese in late 1940[12].

The brief history of the establishment of aircraft repair as well as production facilities covered above brings out very clearly that the Chinese aircraft industry owed its origin and initial development to extensive cooperation with countries that were more technologically advanced in general as well as specifically in the field of aviation. These aircraft factories set up in China had the capability to repair as well as produce aircraft. Production, however, remained rudimentary at the time, in part due to a general lack of skills and technical acumen in the workforce which was a consequence of the less than modern education system then in vogue, and the predominantly non-industrial nature of the Chinese economy. Aircraft design was apparently not carried out at all by the Chinese in the first half of the 20th century. The factories set up in the early 20th century remained just aircraft repair facilities, except for one factory at Hanzhou, that was set up and run in cooperation with the US.[13]

The Nationalist government apparently understood the importance of domestic skills in aviation and took serious steps to remedy the shortfall in human resource quality, especially with regard to high technology fields of endeavour such as aviation, and efforts were initiated to put in place a long-term plan for upgradation of the available human resource quality in the country. Several students were sent to technologically advanced foreign countries, especially to the Soviet Union and the US, to gain modern education well-grounded in science, especially in the field of aerospace technology. By the 1940s, the number of specially selected students sent abroad for such education and training exceeded 1,000.[14] These students included several who later became China's leading experts in different fields of the aerospace industry, from rocket technology to aircraft, aircraft systems, and engine design. At the same time, aviation engineering courses were established at

12. Ibid., pp. 131-135.
13. J. Niosi and J.Y.Zhao, "China's Catching up in Aerospace", *Int. J. Technology and Globalisation*, vol. 7, nos. 1/2, p.81.
14. Mohanty, n.2.

several universities in China, while facilities for research and experiments in aviation such as wind tunnels, were set up at universities with aircraft engineering courses, as well as at aviation factories and research institutes. This heavy investment in the setting up of an education system focussed on upgradation of aerospace knowledge and skills proved to be a boon in later years.

The first aircraft factory in China that did actually build aircraft, unlike the earlier effectively repair facilities, the Central Aircraft Manufacturing Company (CAMCO) was set up in 1934, six years before India built its first aircraft factory. Both countries set up their first aircraft factories in collaboration with the same American company, Intercontinental Aircraft Corporation of New York. Mr Pawley, a senior executive of this company, was involved in the establishment of aircraft factories in both China and India. As in India, the CAMCO aircraft factory set up at Hangzhou manufactured the Curtiss Hawk fighter and Vengeance dive bomber under licence, as the first two combat aircraft to be built in the country.

CHINESE AEROSPACE INDUSTRY POST 1949

The PRC was born through an armed struggle by the Chinese Communists, led by Mao Zedong, who later became the chairman of the Communist Party of China (CPC) against the Nationalists and the Japanese forces of occupation. The CPC was formed in 1921 initially as a study group within the Nationalist Party. The struggle between the CPC and the Chinese Nationalist government was characterised by the foot soldier, only infantry and irregular militia-based armed struggle.[15] While mechanised forces were not used in any major way, application of aerial combat assets in the civil war between the CPC and the Nationalists was negligible. The CPC, at that time, did not possess any military aviation capability. The few Chinese aircraft that existed at the time were owned and operated by the Chinese Nationalist government.[16] A very few relatively inconclusive air raids were

15. Chinadaily.com, "Oct. 1949: PRC is Established", http://www.chinadaily.com.cn/60th/2009-09/01/content_8642545.htm. Accessed on March, 17, 2015.
16. K. Hayward, *The Chinese Aerospace Industry — A Background Paper* (London: Royal Aeronautical Society, 2013), p. 4.

carried out by the Nationalist aviation forces against the Communist People's Liberation Army (PLA). The CPC prevailed over the Chinese Nationalists for a variety of reasons and established the PRC on October 1, 1949.[17] The PRC inherited the few aircraft that the Nationalists had operated in addition to captured Japanese aircraft and personnel. The PRC now also owned the factories set up in China for the Nationalist government in collaboration with the US and other countries in the 1920s, 1930s, and 1940s. Thereafter the PRC was forced, for the next two decades, to rely upon the Soviet Union for its military supplies due to the geopolitics of the time.

After its formation in October 1949, the PRC commenced to build modern military forces and initiated steps to develop its economy and industrial capabilities. Yefim Gordon and Dmitriy Komissarov (2008) in their well-researched book on the Chinese aircraft industry, bring out that the modern Chinese aircraft industry was effectively born on April 17, 1951[18] when the Central Military Commission (CMC) and Government Administration Council promulgated the "Resolution on Building an Aviation Industry". They then go on to describe in detail the progression of the setting up of the aircraft industry in the PRC in the early 1950s, bringing out the following points. The PRC decided to utilise the assistance of the Soviet Union in setting up facilities for production of aircraft. The Bureau of Aviation Industry (BAI) was set up in 1951 as the first authority to supervise the production of aircraft in China. Aircraft factories were set up under the PRC government ownership and control, with Soviet assistance, at several locations such as Nanchang, Shenyang, Chengdu, Harbin, and Xian to manufacture different aircraft. Actual production of aircraft at these factories commenced only in 1954, after the Korean War had ended.[19] Yefim Gordon and Dmitriy Komissarov further bring out that these factories were originally set up to manufacture aircraft under licence. The factory at Nanchang commenced to make the CJ-5 trainer, a copy of the Soviet Yak-18 trainer aircraft, in 1954. This was the first aircraft manufactured in China to achieve a large production run. The CJ-5 was

17. n.15.
18. Yefim Gordon, and Dmitriy Komissarov, *Chinese Aircraft: Chinese Aviation Industry Since 1951* (Manchester: Hikoki Publications Ltd., 2008), p. 7.
19. Ibid., p.7.

followed by the CJ-6, an entirely Chinese developed improved version of the earlier CJ-5, and then the J-5 subsonic jet fighter (a copy of the Soviet MiG-17) made at Shenyang in 1955, the J-6 supersonic jet fighter (a copy of the Soviet MiG-19) from 1959 and the supersonic J-7 (a variant of the Mach[20] 2.0 capable Soviet MiG-21) in 1961. In 1957, manufacture of transport / utility aircraft was commenced at Nanchang with the Y-5, a copy of the Soviet era An-2 biplane; preparations began in 1966 to manufacture the Y-7 (a variant of the Soviet An-24). In 1959, the Harbin Aircraft Factory commenced production of China's first helicopter, the Z-5 (a copy of the Soviet Mi-4 helicopter). Power plants for aviation applications were manufactured at the Zhuzhou plant. As the scope of aircraft building activities steadily increased, the BAI was upgraded to become the Third Ministry of Machine-Building by the end of the 1950s.[21] Towards the late 1950s, the ill-conceived 'Great Leap Forward' launched by Chairman Mao, along with the steady and progressive deterioration in relations between the PRC and Soviet Union affected the Chinese aircraft industry adversely, leading to poor quality of output and stalled programmes. This period also saw the cooling of relations between PRC and the Soviet Union being followed by a total break in good relations in the 1960s. With the break in relations, the flow of technology from the Soviet Union stopped and all Soviet advisers, academics, and technicians were withdrawn from Chinese factories and research institutes. Deprived of the close interaction and guidance of the Soviets, China's aircraft industry was now forced to go it alone. Recovery from the Great Leap Forward led to the 'Cultural Revolution' launched by Chairman Mao in order to reassert his political position. The 'Cultural Revolution' also caused great harm to the Chinese aircraft industry as it laid emphasis on the Communist ideology over scientific and industrial progress. This situation continued till Mao's death in 1976.[22]

In the late 1950s, Chinese aerospace professionals leveraged the education system and knowledge base built up since the setting up of China's first

20. The Mach number refers to a ratio of the speed achieved by a body or fluid to the local speed of sound at those conditions. Thus, Mach 2.0 indicates that the body is travelling at two times the ambient local speed of sound.
21. Gordon and Komissarov, n.18, p.7.
22. Ibid., pp.7-9.

Till the Sino-Soviet split in the early 1960s, the PRC had been building Soviet aircraft under licence with full support in technology and knowhow from the Soviets. After the split, Chinese aerospace professionals were forced to build and develop aircraft totally on their own.

aviation technology focussed universities. These aviation technology focussed universities offered courses in aviation. In addition, the knowledge brought back by students sponsored for aerospace courses abroad was also available. These measures helped China to internalise the knowledge gained through licensed production of Soviet designs. These Chinese aerospace professionals now moved towards building aircraft that involved major modification of the Soviet originals in order to meet local needs. The Soviet era MiG-19-based J-6 supersonic fighter was heavily modified to develop the country's first dedicated strike aircraft, the Q-5, export versions of which are called the A-5.[23] Till the Sino-Soviet split in the early 1960s, the PRC had been building Soviet aircraft under licence with full support in technology and knowhow from the Soviets. After the split, Chinese aerospace professionals were forced to build and develop aircraft totally on their own. This period also led to the realisation in China that it needed to access and import several essential advanced technologies to be able to compete with the global leaders in aerospace.[24]

It is important to understand that technology transfer is not like a tablet that can be swallowed. In order to obtain full technology transfer, the receiver of the technology requires being adequately knowledgeable in the relevant scientific and engineering principles of the concerned domain for the new technology being transferred to be understood by him, and internalised. A layman is unlikely to understand the theory and design philosophy of any new technological product unless he has the scientific and engineering knowledge to absorb it. Fortunately for the PRC, the build-up of skills through sending students abroad and the setting up of aerospace technology departments and

23. Ibid., pp. 143-163.
24. Niosi andZhao, n.13, p.81.

research centres in universities in the country provided a pool of scientists and technicians with the required basic foundation of aerospace design and manufacture who were able to understand and absorb the technology made available to them through licensed manufacture of foreign aircraft.

For the decade of the 1960s, China was forced to go forward totally alone in the aerospace industry due to the impending split with the Soviet Union having come through and China's inability to deal with the West due to the prevailing political situation.

The success of the indigenously designed Q-5 led to the development of the J-8 interceptor in the early 1960s to meet Chinese military needs. The Chinese designers in this case took the J-7, itself based on the initial Soviet MiG-21 design, as the foundation on which to develop the larger and more powerful J-8 interceptor. This programme also saw success with the original J-8 design entering frontline military service and undergoing upgradations and modifications over the years to improve from the original basic supersonic interceptor aircraft to a more able aircraft with some multi-role capabilities and improved avionics and systems. Late versions of the J-8-II and J-8-III continue in frontline service in the PLAAF even today.[25] The development of the J-8 is noteworthy in the context of much of the work on the aircraft development having taken place during the years of Chairman Mao's 'Great Leap Forward' and 'Cultural Revolution', the political movements which led to severe dislocation of all advanced technology industries and infrastructure in China; the fact that the J-8 design team was able to retain coherence and focus during these troubled times speaks volumes about the dedication, management skills and high design skill levels available amongst China's aerospace professionals even in the 1950s and 1960s. During this period, due to the severe dislocation of personnel and resources, most of the output of China's aircraft industry was sub-standard and was often found unfit for induction into service by the PLAAF, making the success of the J-8 even more noteworthy.[26]

25. Gordon and Komissarov, n.18, pp. 75-89.
26. Ibid., pp. 7-8.

For the decade of the 1960s, China was forced to go forward totally alone in the aerospace industry due to the impending split with the Soviet Union having come through and China's inability to deal with the West due to the prevailing political situation. However, from the early 1970s, the situation improved to a great degree for China. In the game of international *realpolitik* and great power manoeuvring, the United States saw advantage in reaching out to the PRC, then estranged from the Soviets, to align against the common enemy, the Soviet Union. This led to exploration through intermediaries of the possibility of normalised relations between the PRC and US. Attempts to rebuild relations between the US and PRC achieved success, exemplified by the visit to Beijing by US President Nixon in 1972.[27] While political peace was made between the PRC and US, and economic ties were enhanced, the situation was not normalised to the extent that completely free transfer of armaments and other cutting edge technology was permitted into the PRC from the West. The movement of high technologies to China from the West was closely monitored by the US as well as by the European agencies. However, despite this reluctance to part with cutting edge technology, several civil and dual use technologies were cleared for transfer to the PRC for the supposedly civil space programme, aimed at enabling Chinese satellites to provide services to improve the lot of the common man, as well as for Chinese aviation, mainly civil.

Through this opening up to the West and increase in economic linkages, China gained considerable access to Western aerospace technology. Chinese aviation firms won contracts to build sub-components for the US McDonnell Douglas MD-82/83 airliners. The MD-82/83 airliners were also fully assembled in China[28]. This licensed production and the inevitable reverse engineering carried out by Chinese scientists and engineers enabled this new phase of international cooperation to fill the gaps in China's indigenous aerospace capability while also introducing advanced Western technologies, concepts and methods into China's aerospace industry. The Chinese imported 13 French SA 321Ja "Super Frelon" medium helicopters in 1977-

27. Niosi, and Zhao, n. 13, p. 82.
28. Gordon and Komissarov, n. 18, pp. 9-10.

78 and promptly reverse engineered them to commence building them in China as the Z-8 in various variants to meet the country's requirements. The principal sub-contracts won by Chinese aviation firms progressively came to form linkages with almost all major aerospace companies in the West; with Boeing, for the manufacture of vertical fins, horizontal stabilisers and rear fuselage; with McDonnell Douglas for the manufacture of the nose section and horizontal stabilisers for the MD-82 and MD-90. In addition, there was a wide array of smaller contracts for aircraft doors, wing sections, turbine disks, blades, bores, rings, atmosphere instruments, meteorological radars, general radar instruments, navigation and control systems, pumps, and valves. The Chinese industry progressed from purely compensation trade, akin to offsets in today's Indian context, to becoming a competitive global supplier of components, including being the sole supplier of some items such as the Boeing-747 wing rear ribs, Boeing-737 maintenance doors, BAe 146 doors, Dash-8 cargo doors and gas turbine components[29].

In these contracts for sub-contract work, the Chinese firms involved had to build components with the quality and reliability expected by Western aerospace majors and conforming to Western civil aviation certification standards. This need forced the PRC's aerospace industry to upgrade its standards and capability on a war-footing, with the inevitable spillover to its military and other purely domestic programmes. Several Western aero-engine manufacturers also commenced to make engine components in China and a few even set up complete engine assembly facilities. This assisted the Chinese in supplementing the knowledge gained from licensed production of Soviet aircraft and engines with equivalent Western knowledge. The latter was usually more advanced and had higher quality and specifications. Many Chinese civil aircraft also began to be made to meet Western airworthiness regulations and with Western power plants to increase their fuel efficiency and export potential[30]. Over time, the involvement of Chinese firms moved to more complex and cutting edge products in terms of their sub-contracting

29. P. Nolan and J. Zhang, *The Challenge Of Globalization for Large Chinese Firms*, UNCTAD/OSG/DP/162 No. 162 (Geneva: UNCTAD, 2002).
30. Gordon and Komissarov, n. 18, p. 9.

deals. Many of these deals had unintended spinoffs. For instance, the performance of jet engines, in terms of thrust, fuel efficiency, and noise signature, is dependent upon not merely the basic engine design and construction, but also on the design of the nacelle that the engine is housed in. The manufacture of Western airliners under licence enabled Chinese engineers and scientists to absorb the then state-of-the-art in the design of engine nacelles amongst other critical design features. This learning could then be utilised in other areas of China's aerospace industry in the design of fighter, utility and transport aircraft.

The development of the Chinese aerospace industry, thus, owes considerably to international cooperation between China and countries that were more advanced in science and technology, in general, and specifically, in the aerospace industry. An important feature of the Chinese experience was the building up of a firm scientific and engineering foundation in aerospace knowledge to enable the absorption of advanced technology. The ability to be able to access both Soviet and Western technologies assisted the Chinese in understanding and internalising both. This put them in a position to make use of the more appropriate technology for each unique situation. Wherever in-country education fell short, they did not hesitate to sponsor suitable people to undergo the required courses in foreign universities or to invite outside experts to help upgrade the system in Chinese universities. Availability of this well trained and highly educated workforce proved crucial in absorbing transfers of technology and even in reverse engineering foreign designs.

The process of configuring the Chinese aerospace industry to enable upgradation of Chinese capabilities in aerospace saw several structural changes as well. The Third Ministry of Machine Building that had been formed in the late 1950s was made the Ministry of Aviation Industry in 1982. Still later, it became the Ministry of Aviation and Aerospace Industry. In 1993, this ministry formed a very large government owned company called China Aviation Industry Corporation (AVIC) as a separate entity. AVIC was a huge company, with almost 500,000 employees and a large number of facilities spread all over China[31]. In 1999, in an attempt to bring in greater efficiency, China established ten new state owned aviation corporations and AVIC was split into two organisations, AVIC-I (which was to prioritise work on large and medium size aircraft, fighters and bombers) and AVIC-II (which was to prioritise light and medium aircraft such as feeder class passenger aircraft and helicopters). The two AVICs were equal economic entities, authorised to operate as holding companies. At that time, both parts of AVIC had approximately 560,000 employees[32]. The two AVICs often had somewhat confusing and even overlapping mandates. In 2008, the two parts of AVIC were merged to once again to form a single entity called AVIC. AVIC has many subsidiary companies engaged in various aspects of the aerospace industry.

Many of the subsidiary companies of AVIC have entered into independent collaborative agreements with Western aerospace companies for sub-contracting work. In addition, these subsidiary companies have, either alone or in concert with other sister companies, undertaken licensed manufacture of foreign aircraft and also design and development work on new indigenous aircraft projects[33].

The preparations for developing the aerospace industry did not stop at just the cooperative arrangements with foreign aerospace firms from technologically advanced countries and industry restructuring. The Chinese had understood as early as in the early 20th century that upgradation of the knowledge and skills of the population were the key to being able to compete in the modern world. Hence, as was seen earlier in this paper, they initiated the twin track programme from the 1920s to 1940s of sending selected students to foreign countries for education in aerospace technologies and, in parallel, of setting up departments of aviation technology in Chinese universities, complete with wind tunnels and other infrastructure, to enable education, training and research to be undertaken. The focus on education and research to develop the human skills continued apace in later years also.

31. Niosi and Zhao, n. 13, p. 82.
32. Gordon and Komissarov, n. 18, pp. 9-18.
33. Ibid.

BUAA maintains a large infrastructure aimed at aerospace education and research. It also utilises international cooperation to keep abreast of the latest technological advances in the world.

Several Chinese universities offer advanced courses in aerospace and aircraft design, engineering and manufacturing. A few of the prominent Chinese universities offering such courses are the Beijing University of Aeronautics and Astronautics (BUAA), Nanjing Aeronautics and Astronautics University (NUAA) in Nanjing, Harbin Institute of Technology (HIT), Tsinghua University (Beijing), and Northwestern Polytechnic University (NPU) in Xian. NPU was established originally in 1938 as the Northwest Institute of Engineering, in Hanzhong, central China; it was moved to Xian in 1957, and was renamed as NPU.[34] BUAA and NUAA were founded in 1952. In 2012-13, BUAA had over 3,300 faculty and staff members, 26,000 students and 88 laboratories. In addition, BUAA had 152 cooperation agreements with over 40 foreign universities and research organisations in the advanced Western countries, including the US, Germany, France, and also with Russia. It also calls over 1,000 foreign experts every year to lecture at the university or to conduct research. In this manner, BUAA maintains a large infrastructure aimed at aerospace education and research. It also utilises international cooperation to keep abreast of the latest technological advances in the world. The sponsoring of research by foreign experts in BUAA could be expected to help induct BUAA faculty and students into the methods and areas of cutting edge research. Such activities could also reasonably be expected to help upgrade China's research infrastructure to world standards. These academic endeavours enable BUAA to produce well trained graduates able to make an effective contribution to China's aerospace industry in addition to the research in aerospace technologies also being carried out at BUAA. The situation with the other Chinese universities offering aerospace courses is similar to that of BUAA, though the scale of staff, students and cooperative arrangements naturally varies somewhat. NUAA, meanwhile, has evolved from being a teaching technical university

34. Ibid., pp. 82-84.

to a dedicated research centre. NPU has an Aircraft Department which was founded in 1952, and its National Laboratory of Aerodynamics Design and Research owns the largest low-speed wind tunnel in Asia, as well as several other wind tunnels. These facilities obviously enable students and faculty alike to carry out research activities in different aspects of aerospace technologies. Tsinghua University, located in Beijing, one of the top higher education institutions in the country, includes China's School of Aerospace[35].

There has been a steady policy of setting up an ever increasing number of educational and research institutes in the aerospace field since the early 1950s in China. The PRC has transformed these into centres of excellence in the respective fields and utilises them to facilitate inward technology transfer from technology owners, in both Russia and the West.

The PRC's institutional infrastructure includes more than 30 government owned laboratories. All of these are placed under AVIC overall. These laboratories cover almost all aspects of aerospace technology. These laboratories are improving steadily and are well manned. The Research and Development (R&D) personnel strength at individual laboratories varies from as low as 110 to as many as 2,500 R&D personnel. The output from these laboratories is also steadily improving[36].

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35. Ibid.
36. Niosi and Zhao, n.13, pp. 83-85.

(CGTE) founded in 1965 is located in Chengdu. CGTE employs 900 R&D staff, and conducts R&D in aero-engine technology. A third one deserving special mention is the Chengdu Aircraft Design Institute (CADI), a subsidiary of the Chengdu Aircraft Industry Corporation. CADI has 1,800 employees including, 1300 technical people who specialise in 80 sub-disciplines of the aerospace industry[37].

Cooperative deals to manufacture aerospace components by Chinese firms for Western aerospace majors has led to China gaining technology for construction of airframe structures, including skin panels and their fitment, composite materials complex structure fabrication, assembly of wings and entire aircraft, Fly-By-Wire (FBW) components and architecture, gas turbine engine components, environmental control systems, landing gears, and navigation and communication equipment. These inward technology transfers have been obtained from a large number of Western aerospace companies through sub-contracts and other cooperative arrangements[38].

Understandably, despite the extensive economic interlinkages, sub-contract work and cooperative manufacturing tie-ups with Chinese companies, the owners of the most advanced technologies were loath to share their very latest cutting edge civil as well as military technologies with the PRC. When faced with such situations, the PRC has demonstrated a pragmatic determination to obtain the desired technologies through resorting to conventional espionage as well as through cyber attack and other technological means such as hacking into computer systems operated by foreign high technology companies and foreign government agencies[39].

INNOVATION IN THE PRC'S AEROSPACE INDUSTRY

The examination of the PRC's aerospace industry brings out the role of innovation also. The PRC adopted an innovative state-led education system to build up a human resource bank of highly qualified and capable aerospace scientists and engineers. It also set up research facilities in several locations.

37. Ibid.
38. Ibid., pp. 85-86.
39. Hayward, n. 16, p. 8.

Thereafter, at the structural level, the PRC tried out several different structures for the domestic aerospace industry to finally settle on the single holding company with a multitude of subsidiary corporations model. In acquisition of technology and advanced knowhow and knowwhy, the PRC utilised licensed manufacturing and sub-component and component supplier contracts to gain access to advanced technology. Where this failed, PRC did not hesitate to utilise conventional espionage and cyber technology to gain access to restricted technology and knowledge. In its manufacturing level also, it displayed great innovation in modifying foreign designs to fully meet domestic requirements. This progressively led on to the design and development of its own equipment.

The PRC has applied innovation in many ways in developing its aerospace industry. Incremental innovation can be seen in the progressive improvement of the Soviet aircraft being built under licence to achieve greater performance and reliability in order to meet local requirements. Disruptive innovation is seen in the Chinese endeavours to build modern aircraft able to compete effectively with the best on offer from the more advanced aerospace powers in the West and Russia. Such a challenge from China, if successful, could overturn the very structure of the global aerospace industry, causing great upheaval in the process.

SUMMARY OF ROLE OF COOPERATION IN DEVELOPMENT OF THE PRC'S AEROSPACE INDUSTRY

To sum up, quite clearly, it is evident that China has successfully utilised international cooperation through sub-contracting work and licensing deals to progressively build up its indigenous capabilities in the aerospace industry. Where the desired technology could not be obtained through these means, the PRC pragmatically resorted to espionage and cyber attacks to gain access to advanced aerospace technologies. The major factor for its success lies in the PRC's decision to establish an effective education and scientific research infrastructure especially focussed at upgrading the country's knowledge and skill levels in the field of aerospace technology. This effort formed the foundation that has enabled the PRC to effectively absorb and internalise technology from disparate sources. Today, China possesses the full range of aerospace specific design and development, testing, production, marketing, upgrading, in-service product support, and management capabilities. These make the PRC one of the few countries in the world with the capability to design and manufacture the entire range of aircraft and associated systems. The presence of a large domestic market gives the Chinese aerospace industry scope to grow in the near to medium term future to a level where it is able to present a viable challenge to today's world leaders in aerospace technologies and products. China has also cooperated with the less advanced countries in the aerospace industry. An example is cooperation with Pakistan for the K-8 'Karakoram' jet trainer and the JF-17 'Thunder' / FC-1 'Xiaolong' which in translation is 'Fierce Dragon' fighter. In both these cases, Pakistan, with its greater exposure to Western aircraft, helped set the performance parameters and through licensed production, helped secure a larger production run for the aircraft. The launch export customer for both the K-8 and FC-1 / JF-17 was Pakistan. This initial sale helped increase the orders for the aircraft as well as to generate interest in other customers for the same aircraft. Pakistan which builds the JF-17 under licence from CAC has also displayed this aircraft at international air shows[40]. The K-8 / JL-8 jet trainer is operated by Egypt, Ghana, Myanmar, Namibia, Pakistan, China, Sri Lanka, Sudan, Tanzania, Zambia, and Zimbabwe[41].

DEVELOPMENT OF THE AEROSPACE INDUSTRY IN BRAZIL

The Political Situation and Early Aviation in Brazil

Brazil was, since the time of European colonial expansion into South America, a plantation colony under Portuguese control. In 1822, the ruler of Brazil declared its independence from Portugal. The first republic was declared in 1889 after a *coup d'état*. This republic lasted till 1930. However,

40. Business inquirer.net, "Pakistan Sells its JF-17 Fighter Jet at Paris Air Show", http://business.inquirer.net/193568/pakistan-sells-its-jf-17-fighter-jet-at-paris-air-show. Accessed on May 26, 2016.
41. Airforce-technology.com, "K-8 Karakorum Light Attack and Jet Trainer Aircraft, Pakistan", http://www.airforce-technology.com/projects/hongdu-k8/. Accessed on May 18, 2016.

though nominally democratic, in reality, power during this first republic was concentrated in the hands of a few large landowners. Mr. Vargas, a leader with fascist leanings, seized power in a bloodless coup in 1930. He then ruled for 15 years till 1945, when he was overthrown in another bloodless coup, ushering in a democratic system of governance. However, political instability in the post-World War II years led to a military coup in 1964. The military then ruled the country till 1985.

Early Brazilian Aviation Innovators

Alberto Santos Dumont was born in Brazil in 1973, to a rich coffee planter. At the age of 18, he went to Paris for his education. While in Paris he commenced experiments with hot air balloons, including developing steering mechanisms for these devices. This led him further towards dirigibles. After solving the problems with hot air balloons, he turned his attention to heavier than air flight. After several attempts between September and November 1906, he achieved a series of flights of a maximum of 220 metres (m) distance at a height of 6 m above ground level[42]. Dumont is regarded in Brazil as the pioneer of flight, in that, unlike the Wright Brothers, he completed his first flight, including an unaided take-off from flat land, straight level flight and landing without any ramp or such device. Moreover, this feat was conducted on a fixed day and not based on prevailing weather, especially wind, conditions. Also, it was done in front of witnesses and judges. Dumont is a hero in Brazil and his feat enthused the country about aviation[43].

DEVELOPMENT OF AEROSPACE INDUSTRY IN BRAZIL

The Brazilian Aeronautics Ministry was created on January 21, 1941. Its objective was to develop, expand and coordinate the activities of the technical and economic aspects of national aviation. It sought the ends of both technological progress and national security.

42. Smithsonian.education.org, "Highlights in Aviation Alberto Santos Dumont", http://www.smithsonianeducation.org/scitech/impacto/graphic/aviation/alberto.html. Accessed on March, 17 2015.
43. A. Downie, "A Century on, Brazil Still Claims Flight's First", http://www.csmonitor.com/2006/1023/p07s02-woam.html. Accessed on March, 16 2015.

In 1954, the Institute for Research and Development (IPD) was also set up within CTA. IPD's departments included aircraft, electronics, materials, and engines. IPD's objectives included testing and approving new aircraft developed in Brazil or those modified in Brazil.

At the end of World War II, a group of *Força Aérea Brasileira* (FAB), the Brazilian Air Force officers led by Brig. Casimiro Montenegro, in collaboration with the Massachusetts Institute of Technology (MIT), began to plan the establishment of a Brazilian aircraft industry. On January 29, 1946, this body was named the Organising Committee of Aeronautics Technical Centre (COCTA)[44].

COCTA was tasked to establish the scientific and technical body of the Ministry of Aviation. This scientific and technical body of the Ministry of Aviation, called the Aeronautics Technical Centre (CTA) was officially established at Rio de Janeiro on March 25, 1949. The city of São José dos Campos (SP) was chosen to host the facility's technology centre due to its favourable topography, availability of adequate electricity supply, and comfortable climate. Its job done, the COCTA was disbanded in 1953.

A premier national level training institute, the Aeronautics Technological Institute (ITA), was established on January 16, 1950. ITA was headquartered at the CTA's Department of Science Aerospace and Technology (DCTA). The CTA and its ITA were transferred from Rio de Janeiro to Sao Jose Campos in 1950. The aeronautical engineering course taught at the Army Technical School at Rio de Janeiro was also transferred to the ITA.

The class that commenced its course in 1947 at Rio de Janeiro graduated in 1950 from San Jose dos fields. The students at ITA were all national scholarship holders who were provided free tuition as well as free boarding and lodging, with health care included[45]. Progressively, ITA began to offer courses in other specialisations with relevance to the aircraft industry such as electronics, mechanical engineering, and aeronautics infrastructure. In

44. Embraer.com, "Our History", http://www.embraer.com/en-US/ConhecaEmbraer/our/Pages/default.aspx. Accessed on March, 16 2015.
45. J.E. Cassiolato, *Transfer of Technology for Successful Integration into the Global Economy* (New York and Geneva: United Nations, 2002), p. 11.

addition to graduate level courses, it later began to offer Masters and Doctoral level courses also.

In 1954, the CTA's new facilities at Sao Jose dos Campos were being built. CTA was the scientific and technical body of the Ministry of Aeronautics. It was to carry out activities on behalf of the FAB, civil aviation and the aviation industry, according to the plans and programmes of the Aeronautics Ministry. In addition, the CTA's mission was to conduct scientific and technological research projects in order to increase the available knowledge base.

It can be seen that over time, the country focussed almost all its aviation facilities at one location. These facilities included education, training, design and manufacture and R&D facilities. Such colocation could have advantages of better coordination and utilisation of resources.

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It can be seen that over time, the country focussed almost all its aviation facilities at one location. These facilities included education, training, design and manufacture and R&D facilities. Such colocation could have advantages of better coordination and utilisation of resources. In 1951, a unique aircraft development project called the Convertiplano, was initiated. This machine was to feature a single engine driving four propellers. This machine was designed by the CTA and DCTA and German Professor Heinrich Focke, the German pioneer designer of helicopters, was the team leader for this project. The Convertiplano was designed to take off like a helicopter and then to fly horizontally like a normal aircraft[47].

Private companies to make aircraft in Brazil started to be formed in the years after World War II. In 1954, businessman José Carlos de Barros Neiva founded the Indústria Aeronáutica Neiva. This company was initially

46. Downie, n. 43.
47. n. 44.

located at the airport at Rio de Janeiro but later moved to Botucatu city. It started to design and manufacture gliders. But, in later years, it went on to manufacture the light aircraft Paulistinha, a light trainer for civil and military use of which as many as 800 were produced for use in Brazil as well as in its neighbouring countries. This aircraft was manufactured till 1967[48]. Later, this company produced the Regent U-42, a four-seat high wing monoplane for observation duties in military use. The U-42 design started in 1959, and first flew in 1961. A civil version was also developed. Another version for the FAB had a provision to carry light armament[49]. This company later produced more designs similar to the U-42, in collaboration with American light aircraft firms. In 1960, Nevia opened an engineering centre in Sao Paolo dos Campos where CTA was also located[50]. A few other small companies to manufacture light aircraft were also set up in various parts of Brazil in the post-World War II years[51]. Till the 1960s, all aircraft manufactured in Brazil had been light aircraft. In 1964-65, a medium size aircraft able to carry up to 20 passengers was cleared for development by the government and the project was initiated at CTA.

The Brazilian military was vocal in its view that for effective security, the country could not rely upon imported equipment for its aviation users, and required to design and build aircraft within the country. In the years immediately after the military coup in 1964, the earlier close cooperation between the military and public sector technicians was revived. The most important event in the decade of the 1960s from the aviation viewpoint in Brazil was the formation of Embraer (Empresa Brasileira de Aeronautica – Brazilian Aeronautical Corporation) in 1969. The Brazilian government held a majority stake in Embraer.

Embraer was formed as a state owned and operated concern[52]. It took over responsibility for developing the twin turboprop 20 passenger aircraft, called the Bandeirante, which had been assigned to CTA a few years earlier.

48. Ibid.
49. Ibid.
50. Ibid.
51. Ibid.
52. This was similar to a Public Sector Undertaking (PSU) in the Indian context.

The government provided a lot of support to Embraer through avoidance of red tape, in terms of orders, international agreements as well as finance from state-owned banks[53]. Embraer started production of aircraft in the 1970s in collaboration with foreign partners.

This strategy was chosen to avoid technological bottlenecks and to achieve rapid sales and economic sustainability. In addition, Embraer decided to avoid vertical integration[54]. It was feared that vertical integration may lead to fragmentation of the industry, with efforts being devoted to too many subsidiary aspects of the aircraft industry. Instead, Embraer decided to focus just on designing aircraft, producing the fuselage and assembling the final product. Embraer wilfully refrained from investing in the manufacture of high technology high value components that could require significant resource allocation, alongside possible time and cost overruns[55]. In pursuit of this avoidance of a vertical integration strategy, in the 1970s, Embraer signed long-term supply contracts with various component suppliers.

The Embraer designed Ipanema light agricultural aircraft flew in 1970. Embraer commenced manufacture of the Xavante under licence from Aermacchi in 1971. In 1978, the FAB tasked Embraer to develop a training aircraft to fill the gap between basic trainers and operational aircraft. The output of this project was the EMB-312 Tucano. Embraer's two best selling aircraft were the Tucano military trainer and the Bandeirante twin turboprop unpressurised aircraft. Both these aircraft were designed in Brazil but of the latter's value, more than half was imported[56].

Embraer carried out fruitful collaborations with Italian aircraft manufacturers in building the Xavante jet trainer, the Aermacchi MB-326, originally, under licence from Aermacchi. In this deal, several Embraer technicians were sent to Aermacchi's facilities in Italy to assimilate the

53. A.Goldstein, *Embraer: From National Champion To Global Player* (Paris: OECD, 2002), p. 100.
54. Vertical integration refers to a company carrying out most upstream and downstream activities involved in making its main product in-house. For example, if a steel company was involved in ore mining, its transportation to factories and shipping of finished products to the market, it would be a vertically integrated company. China's aircraft industry is vertically integrated as it makes all the components required itself.
55. OECD, N-217.
56. Goldstein, n. 53, p. 100.

technology involved in the aircraft's production. This process helped internalise the knowledge gained in licensed production of the Xavante. Later, the AMX light fighter/ground attack aircraft was developed and manufactured, in cooperation with Aeritalia and Aermacchi.

Brazil also used the threat of a sharp increase in import duties to force manufacturers of general aviation light aircraft to manufacture their products in Brazil. Piper of the US that followed the Brazilian 'forced path', increased its share of the Brazilian light aircraft market dramatically over its competitors Cessna and Beech. This process helped Brazil gain technical and organisational knowledge in series production[57]. Embraer also initiated a process of encouraging local privately held firms to supply an increasing number of components for its products, thus, setting up an aviation eco-system in the country. Embraer maintained a strong focus on exports. This export orientation enabled larger production runs, covered the costs of development and production, and forced the company to comply with international certification standards while also demanding exacting quality standards.

Embraer also decided to capitalise on building aircraft for harsh climatic, environmental and infrastructural conditions. It aimed at building rugged aircraft able to operate from backward areas, with minimum support infrastructure, often from compacted dirt airstrips, and at low cost, with ease of maintenance built into the design. This strategy delivered great success to the company[58]. Embraer achieved success of sales of its Bandeirante commuter aircraft and Tucano trainer by developing and selling products that were not as advanced as those on offer from Western companies but served the purpose, with innovative design features to achieve high performance at a relatively low cost point. In the 1980s, despite financial troubles, Embraer introduced the EMB-120 Brasilia and a 30-seat pressurised twin turboprop aircraft derived from the Bandeirante. In the 1980s, Embraer got the Brazilia certified for operation, and the Tucano turboprop trainer, and the light aircraft Xingu were successfully exported to the highly competitive

57. Ibid., p. 100.
58. Ibid., p. 100.

European region, while Embraer commenced development of its EMB-145 series of jet propelled commercial aircraft. Meanwhile, the first AMX built in Brazil was rolled out and delivered. The world recession of the late 1980s and increased protectionalism of the advanced economies, however, forced Embraer into a dire financial situation[59].

In December 1994, Embraer was privatised. The government continued to hold a stake in the company and also held a golden share, thus, holding veto power in company activities. Other conditions of the privatisation included a limitation of 40 percent on foreign ownership, a six-month moratorium on layoffs, and strictures banning major changes in business directions. The company also underwent an internal renewal process to improve efficiency and competitiveness[60]. Privatisation was used as a tool to make the company more efficient and productive while still retaining government control through the golden share.

In the 1990s, Embraer continued to design and build more jet powered aircraft for the short haul and business aviation markets. In order to address assessed markets, Embraer developed the ERJ 135 and the Embraer 170 and 190 aircraft in addition to its Phenom and Legacy series of business jets.

ANALYSIS OF EMBRAER'S SUCCESS

After privatisation, Embraer has restructured to reduce costs, including outsourcing several administrative and routine maintenance services and tasks. Embraer continued development of its regional jets of close to 50 passenger seats each on seeing an emerging market for these. Later, it developed other aircraft with less as well as more seats. The basic strategy of Embraer did not change.

Embraer continued to aim for the world market more than trying to service the domestic market alone. This is shown very clearly by the revenue break-up of the company. From 1997 onwards, more than 80 percent of Embraer's revenues have come from the export market. This percentage increased to

59. Ibid., p. 100.
60. Ibid., p. 100.

over 95 percent from 1999 till 2001 at least[61]. The turnover of the Brazilian Aerospace Industry in 2005 was $ 3.41 billion[62]. In the years 2012 to 2014, the revenues were above $ 6 billion, peaking at $6.29 billion in the year 2014[63]. In 2015, revenues fell slightly to $ 5.93 billion[64]. Of this, 90 percent was from export sales.

In another division, 87.3 percent of the revenues came from activities in aeronautics, 9.29 percent from defence and 0.24 percent from space[65]. Thus, Embraer has focussed primarily on the civil market with defence and space activities contributing a mere 9.29 per cent and 0.24 per cent of Embraer's revenues.

Embraer has cooperative agreements with companies in the US, Europe, China, Asia, and Africa. These cooperative agreements span a diverse range of activities. Some agreements are in relation to Embraer sourcing components, parts, and equipment for its products. Others are for sales and servicing of its aircraft, and still others involve Embraer cooperating with companies in other geographical locations to build its aircraft designs under licence. Embraer is the fourth largest aerospace company after Boeing, Airbus and Bombardier. It competes against Bombardier in the short haul regional airliner and business jet markets. Embraer's aircraft fly in the skies of all continents. Without doubt, Embraer is a major success story of how the aerospace industry in a developing country was able to develop its capabilities to an extent where it is able to compete head to head with some of the most advanced aerospace companies in the world.

THE ROLE OF COOPERATION IN BRAZIL'S AEROSPACE INDUSTRY

Cooperation, as seen earlier in this paper, has played a very prominent role in the development of Brazil's aerospace industry. In fact, this aspect

61. Ibid., p. 103.
62. Statista.com, "Embraer's Net Revenue from FY 2005 to FY 2015 (in billion U.S. dollars)", http://www.statista.com/statistics/269936/net-revenue-of-embraer-since-2005/. Accessed on May 18, 2016.
63. Ibid.
64. Ibid.
65. W.Bartels, "Aerospace Industries Association of Brazil: Aeronautics in Brazil",(presentation delivered in Vienna/, Austria, on June 19-21, 2006).

of cooperation continues to play an even larger role today than it did in the past. Brazil used cooperation with the more advanced countries to gain knowledge of the state-of-the-art in aerospace technologies elsewhere in the world. This took the form of licensed manufacture of foreign designs. Internalisation of the knowledge gained was assisted by the presence of a well-educated and trained pool of aerospace professionals. Brazil's Embraer opted to avoid the traditional path of aircraft manufacturers of making almost all the required parts itself and focussing on just design, airframe construction and integration of all components to complete the machine from the very beginning of its foray into the aircraft industry. Boeing and Airbus adopted a similar strategy only in the late 1990s[66]. At the time that Embraer opted for this strategy, there was no precedent in the aircraft industry to help hazard a guess about its feasibility. The strategy worked for Embraer, and, in hindsight, this proved to be prophetic.

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Today, even legendary names such as Boeing in the US are airframe manufacturers and integrators of all the components that go into an aircraft. The components, parts and even sub-assemblies required for an aircraft, while these may be designed or their performance characteristics decided at Boeing, are manufactured at locations as diverse as the US, Asia and even Africa, in search of efficient manufacturing to the required quality at the least cost. The reason that Brazil has been able to reach the position of Embraer being the fourth largest aerospace company in the world, ahead of China, despite

66. N-217, N-219, N-220; Mustafa Erdem Sakinç, "Systems Integration in Question – A Comparison of Airbus and Boeing", International Research and Regulation Seminar, Paris, June 10-12, 2015, pp. 2-12.

the latter's size and resources, may lie in the international cooperation and airframe maker and integrator business plan chosen by Embraer. Brazil also relied upon international cooperation to set up its aerospace infrastructure. MIT of the US was asked to assist in setting up CTA and its subsidiary departments and facilities.

Embraer continues to follow its strategy of designing the aircraft overall, building the airframe and integrating component and sub-component parts sourced from a large number of vendors both within Brazil and from other countries. Such a strategy inherently relies upon cooperation for success.

Embraer has active cooperative arrangements with companies and facilities in the following countries:

- Belgium.
- Chile.
- China.
- France.
- Germany.
- Italy.
- Japan.
- Spain.
- Sweden.
- United Kingdom.
- United States.
- Russia.

These partnerships include sourcing of complete components, co-development of technologies and components, risk sharing in the overall Embraer project by component suppliers, testing of designs in test facilities such as wing testing in Russia's TsAGI's transonic wind tunnel, licensed assembly of Embraer aircraft and technology transfer, both inbound and outbound[67].

The examination of the aerospace industry in Brazil and China brings out the importance and relevance of international cooperation for the

67. Golgstein, n. 53, pp. 108-112.

effective development of an aerospace industry. Thus, it can be concluded that cooperation between countries less advanced in aerospace and those more advanced in this field is desirable for the less advanced country to achieve inward transfer of technology. However, the caveat is that the technology receiving country should have an education policy and system that can prepare a sufficiently large number of personnel educated and trained in aerospace knowledge and skills, including to the advanced levels of Masters and Doctoral levels in education and state-of-the-art cutting edge technology and designing concepts, manufacturing, integration skills. Such personnel, if up to the speed on the technology available in the country and with an educated view of the more advanced technology being developed elsewhere, would be the key in effective inward transfer of technology and its internalisation. Cooperation between countries having about the same level of technology in aerospace is also desirable. This helps each learn from the strengths of the other to fill any gaps that may exist in each part's capabilities[68]. A spinoff is the larger production runs potentially possible, with economies of scale being a benefit. Thus, Embraer licenses the manufacture of its aircraft to Chinese companies to achieve sales in China and to gain potentially low cost parts suppliers, while the Chinese learn from Brazil's strengths in short haul aircraft design and manufacture. The end result is a win-win situation for both countries. It goes without saying that the capabilities in the two cooperating countries should be complementary for this strategy to succeed. For example, Brazil imported fighters from Europe, the Mirage-III earlier and now the Swedish Gripen, but exported the Tucano trainer and light commercial aircraft such as the Xingu and its regional jets to European operators. The two case studies of China and Brazil offer pointers towards successful cooperation.

68. An example of this is the cooperation between China and Brazil. China has a more rounded multiple capabilities-based aerospace industry which, however, has till date been unable to match global standards in design, efficiency and certification, especially in the area of civil aviation products. On the other hand, China has the ability to carry out quick and efficient low cost manufacturing and advanced R&D in many aspects of the aerospace industry. Brazil is a world leader in designing and integrating commuter and short haul civil aircraft. Thus, the ongoing cooperation between them through assembly of Embraer's regional jets in China helps each party learn and benefit from the other's key competencies that are lacked by the other partner.

ROLE OF INNOVATION IN BRAZIL'S AEROSPACE INDUSTRY

Apart from the role of cooperation, the aspect of innovation has also been at play in the development of Brazil's aerospace industry. Brazil's first aviator, Alberto Santos Dumont, displayed remarkable technical innovation in his experiments, with steerable hot air balloons and dirigibles in Paris, leading on to his heavier than air aircraft designs. In Brazil, the setting up of an aerospace industry by the government displayed innovation in the first instance in establishing a training and research centre for design and development activities. Thereafter, the country utilised cooperation to gain access to technology that could be readily internalised. The first aircraft to be designed in Brazil, the Convertoplano, featured the innovation of a single engine driving four different propellers. Later, Brazil chose the niche of rugged and easy to maintain aircraft able to operate in less developed regions with little aviation infrastructure as its Unique Service Proposition (USP). In addition, it eschewed establishing of its presence in all parts of the aviation industry to being a designer, airframe builder and integrator alone, well before this strategy was the norm in other countries. For its products, it was one of the first to choose to build regional commuter aircraft, trainers and light business aviation aircraft and short haul airliners only[69]. Embraer also decided to focus on the export market much more than its own domestic market. These innovations have helped it to achieve success in the highly competitive global aerospace market.

CONCLUSION

The brief examination of the development of the aerospace industries in the PRC and Brazil brings out similarities between them in their formation. In both cases, the governments in power recognised the importance of an independent and capable aerospace industry. The governments also understood the importance of modern education, especially in aerospace disciplines. In both cases, first, a pool of educated and trained personnel was

69. Boeing, Airbus, Dassault , etc. all produce a wide range of aircraft, while Bombardier, that specialises in business jets and short haul airliners such as those marketed by Embraer, entered the aviation arena in 1986 by buying Candair, which company had earlier built a wide range of aircraft..

built up. The PRC's and Brazil's military also understood the importance of being self-sufficient in aerospace technologies and products and so gave wholehearted support to their domestic aerospace industries. In both cases, the most suitable students available were chosen for undergoing education in the aerospace field, both within their parent countries as well as in the more advanced countries. Also, an effective infrastructure for education, training and R&D in aircraft technologies was established. This was done with active government support and through obtaining guidance and assistance from leading education, training and R&D institutes in the more advanced countries. In this process, international cooperation was utilised to set in place the necessary infrastructure and specialised scientific knowledge in aerospace technologies. Such international cooperation, as covered earlier, involved asking leading institutes of scientific research for assistance in establishing syllabi, research facilities, and to train faculty. Exchange programmes, for faculty and students, with these leading scientific institutes were maintained in later years also. Thereafter, licensed production of aircraft was undertaken more with an aim to internalise new knowledge. The presence of a pool of well-educated and motivated personnel made this technology transfer possible. Thereafter, the PRC, for its security compulsions, decided to engage in the full process of aircraft design, development support and maintenance, including the main structure and all components and sub-components. Brazil, on the other hand, opted to design and build airframes and to integrate the components and sub-components as the designer-integrator. It chose to avoid investing in high technology areas that could result in cost and time overruns. Both these aerospace industries were initiated under government control as state-owned and operated enterprises; the PRC's aerospace industry continues to be state-owned and operated, while Brazil privatised its aerospace industry over two decades ago. The PRC is competitive in the military aspects of this industry, while Brazil has achieved global competitiveness in its chosen field of regional and business jet design, sales and support. In addition, it has one tandem seat turboprop trainer, the EMB-312 "Tucano", which is also offered in the EMB-314 light attack variant[70]. The Tucano has achieved several export sales including to the UK and France.[71].

LESSONS AND LEARNING FROM THE CASE STUDY

Three major takeaways from this examination are:

- Firstly, the importance of the government and defence forces recognising the importance of domestic self-sufficiency in the aerospace field.
- Secondly, the need to build up a good base of well-educated and trained aerospace personnel comprising scientists, engineers and skilled workmen to be able to develop aerospace technologies, and
- Thirdly, the utilisation of international cooperation and innovation to internalise technology transfers from the more advanced countries for own benefit.

70. Embraer.com, "Tucano Operators Conference", http://www.embraer.com.br/en-us/imprensaeventos/press-releases/noticias/pages/embraer-organiza-a-1-conferencia-dos-operadores-do-tucano.aspx. Accessed on May 26, 2016.
71. Of the industrially advanced countries, the EMB-312 trainer aircraft was flown by France and the UK. France ordered 80 Tucano aircraft in the early 1990s. The order for 80 was reduced to 50, with induction starting in 1994. These aircraft were withdrawn from service after 15 years despite many flying hours remaining on them. airforce-technology.com, "EMB-312 Tucano Trainer Aircraft, Brazil", http://www.airforce-technology.com/projects/emb-312-tucano-trainer-aircraft/. Accessed on May 26, 2016.