Air Commodore Jasjit Singh on

The Challenge

ADA-designed, HAL-built Tejas Light Combat Aircraft at Aero India 2013 (photo : Angad Singh)

The Case of the Aircraft Industry*

It appears curious and inexplicable to most students of national security and defence that in spite of an aircraft industry that has expanded enormously since 1939 when it was set up, India has been forced to import almost all types of complete aircraft from foreign sources. A small degree of self-reliance was achieved by licensed manufacture of some of the aircraft. But the high-technology systems and components for these also were imported. At one level, this can be explained by the reality that the country was deindustrialised during the two centuries before independence. The Industrial Revolution had started in England three centuries before India's independence. As industrialisation grew and expanded geographically to Europe and North America, muscle power gave way to machine power for economic productivity.

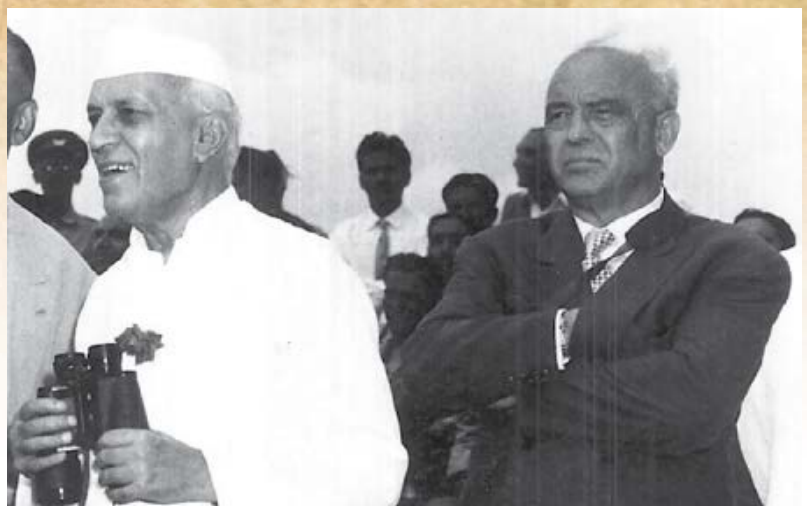
Growth and advances of technology, especially in its military application, as the natural consequence of the industrialisation of England and Europe, also provided significant military advantage over the local and regional regimes and became the source of capability to establish empires in the rest of the world. The colonial powers of Europe did not set up any industry in the countries they ruled, and focussed on military technological

# of Indigenisation

"No country is really independent unless it is independent in matters of its armament."
Jawaharlal Nehru

superiority and further advancement of their own industries with resources and raw materials from the colonised countries. Japan, however, did create numerous industries in Manchuria when it invaded China. China had also grown with massive transfer of military and civil industries, lock, stock and barrel by Stalin's Soviet Union in early 1950.

While some "sunset industries" like textiles had been transferred to India by the British (after British labour costs began to rise), India's industrialisation really began after independence. In fact, there was serious difference of opinions among the leaders of the Indian National Congress which had spearheaded the struggle for independence, on whether India should adopt a village-based cottage industry or try an invest in heavy industries



The inspiration and the muse : Jawaharlal Nehru and Kurt Tank watch the HF-24 in flight in 1961. An ecstatic Nehru exclaimed that the aircraft was like "a gazelle of the air."

After test flight of the HF-24 Mk.IT tandem seating trainer at HAL, Bangalore

like steel, cement and power generation, etc. Perhaps both strategies could have been followed if financial resource and techno-economic aid had been forthcoming. Nehru's vision of modern industrialised India with village-based development appears to have provided the mixed economy which over the years has succeeded in moving the country toward substantive socio-economic development. From our perspective of indigenisation of military weapons, especially aircraft and their peripherals, we have lagged behind perhaps due to the Indian mind emphasising on "cutting edge" technology. But the Indian mind also tends to focus much more on the theoretical rather than the practical application of that theoretical knowledge: for example, there is great emphasis on political science and very little on international relations, etc.

We need to constantly keep in mind the reality of the centuries of deindustrialisation which had the country way behind the developed countries and even behind China, which got significant infusion of industrialisation. Hence, India has had to condense into decades, its industrial technological revolution, which the developed world achieved in centuries with the added' benefit of resources from the colonised countries. Contrary to conventional wisdom, India did/does not possess any significant natural resources. Its only asset for two centuries has been its human resource which was fully exploited by the British in areas ranging from transportation of labour to work in plantations as far as the Caribbean, Fiji, South Africa, Kenya, Myanmar (then Burma), Malaya, etc., though the greatest exploitation was of Indian soldiers in the Imperial Wars. The raw materials produced by the country like cotton, iron ore, etc., were exported to run textile mills in England. Hence, we need to judge our ability/inability to achieve self-reliance in armaments keeping in view the handicaps that our history placed on us in the past when the developed industrial countries enjoyed the benefit of unlimited access to resources.

It is also true that HAL (now Hindustan Aeronautics Limited) has manufactured many hundreds of combat aircraft, and overhauled thousands of aero-engines for combat and transport aircraft. But, more important, after independence, it started on the ideal vector which would rely on three parallel processes: (i) indigenous design and development even if it required collaboration with foreign expertise; (ii) licensed production of weapons and equipment in the country, presumably including every sub-system and component down to the nuts and bolts; (iii) direct import of urgent and high-technology aircraft and systems to meet operational requirements, with licensed manufacture to complete the full complement of aircraft required. When looked at closely, the last process mostly has become another aspect of the second process, that is licensed assembly and production for an aircraft/system designed abroad in which HAL was not, and could not have been, a party. When the government proudly announced, every time a contract was signed, that this would be accompanied with TOT (Transfer of Technology), what it really meant was that production technology would be available.

The all-Indian HF-24 Mk.IT could well have admirably served as a lead in fighter trainer during the decades that the IAF was yearning for an advanced jet trainer.

HAL-built Avro (HS) 748 medium transport aircraft, now sought to be replaced by a modern type, and one which the IAF would like built by a JV between an international OEM and Indian private sector partner. (photo : Angad Singh)

HAL-built Dornier 228 light transport aircraft which is used by the IAF for logistic air support, air staff transportation and multi-engine conversion training. The Indian Navy and Coast Guard operate large numbers of the Do 228 for maritime reconnaissance, coastal patrol and information warfare tasks. (photo : Angad Singh)

Designed & developed by HAL with technology support from the erstwhile MBB of Germany, the Dhruv advanced light helicopter (ALH) is now in series production and serving with the Indian Army, Air Force, Navy and Coast Guard.(photo : Army Aviation)

The official terminology in the Ministry of Defence was a choice between "buy" and "make," the former without any licensed manufacture and the latter, including manufacture under licence. A typical example is that HAL manufactured around 600 MiG-21 variants. But when HAL designed the "combat flaps" to enhance the air combat capability of the aircraft, it could not introduce that in the fleet. Similarly, when it was finally decided to upgrade the MiG-21, the Russians had to be involved in the process and paid for their labour though they were not really needed.

The Chinese, of course, do things differently. For example, they purchased the Sukhoi Su-27 air superiority fighter from Russia in early 1990 under a contract that specified 24 aircraft outright imported and the balance to be assembled and manufactured in China. It acquired the Su-30MK after that on similar terms and realised that the platform was the same as that of the two-seat Su-27 trainer. It copied most of the systems of the Su-30 and cancelled the Su-27 contract and began to manufacture it modified to the Su-30 standard, and called it the J-11. The Russians were livid; but they needed the hard currency and exports to China, especially of the high-powered jet engines which China (like India) is unable to produce indigenously.

HAL-built MiG-21bis in afterburner takeoff. In this eminently successful and long term relationship with the Russian (nee Soviet) aviation industry, nearly 600 MiG-21 variants were built by HAL between 1966 and 1987.

125 MiG-21bis aircraft were subject of major upgradation to 'Bison' standards.

Looking back at the triple process of building indigenous capacity while meeting the operational demands of the Indian Air Force (IAF), the third process, viz., outright buy, especially high-technology aircraft and systems, has continued. The second process of relying on licensed production actually received a boost after the Sino-Indian War of 1962 when the IAF was authorised to expand from 25 squadrons to 64 squadrons. The Soviet Union did not demand hard currency payments which it would have been unable to spend given the complete ban by the West on economic and trade relations with it. For an India perennially short of hard currency, trade with the Soviet Union on rupee payment appeared as a boon in spite of the rupee-rouble exchange being pegged on a basket of Western currencies, thus, significantly costlier to India than its face value. But Soviet aircraft and systems rapidly increased in technological quality and served the IAF's (and the other two armed forces') operational purposes.

Moscow soon began to offer even long-term credit at very low interest rates to ensure that the rupees it earned in this trade would sustain for a long time to enable it to use them to purchase consumer items like medicines, rice, tea, hosiery, textiles, etc. from India. HAL set up additional plants for the licensed manufacture of Soviet designed aircraft (at Nasik in Maharashtra) and engines (at Koraput in Orissa) at two opposite ends of the country. Incidentally, Koraput is not even connected by rail (or an airfield anywhere close by) and all engines manufactured and overhauled at this factory had to be moved on hired trucks thousands of kilometres away from Nasik IAF air bases across the country. This inevitably led to increased costs and inefficiency, with an impact also on aircraft serviceability in the operational squadrons. The direct negative result of this process was that licensed manufacture of Soviet aircraft and arms became the dominant part of the three parallel processes we identified above. Above all, successive governments became complacent.

HAL is currently producing the Sukhoi Su-30MKI at its Nasik facility, with its AL-31FP engines being assembled at Koraput. Some 270 numbers of this 'air dominance' fighter will serve with IAF for the next three decades, including those imported as fly aways.

There is no doubt that the efforts to diversify the sources of supply had become a way to achieving a lower level of self-reliance since it reduced the dependence on anyone country. But in the ultimate analysis, this had long ago settled down to two-odd countries: the Soviet Union and two European manufacturers (the UK and France) of aircraft and associated weapons and equipment. On the other hand, piecemeal acquisitions (like that of the Jaguar) only led to cost escalations and we denied ourselves economies of scale. But none of them was converted into joint ventures and nor was design data transfer part of the licensed manufacture contracts. So we could not even modify the aircraft we were manufacturing in the country.

The major casualty of this complacency was the first of the three processes identified above: indigenous design and development. It is pretty obvious that indigenous design and development is the foundation on which overall indigenisation for self-reliance can be built. The other two processes could at best serve as an interim step till a country reached self-reliance in design and development capability. Hence, India's march toward indigenisation is at best a one-legged effort and it will be a very long time before Indian pilots would be able to fly a modern Indian designed combat aircraft. I recognise that many people would angrily question the above conclusions at the very start of this study. I can hear loud noises about the Light Combat Aircraft (LCA). But this actually proves the central point being made.

The LCA was conceived in 1979-80 as an incremental approach to design and development of a low cost fighter for battlefield support to the land forces to replace the MiG-21 beginning 1985-86 and building 450 aircraft as the "workhorse of the IAF" as Mr Arun Singh, the Minister of State (MoS), Defence, used to say. Three key deficits of the otherwise excellent MiG-21 (which shot down two F-104 Starftghters of the Pakistan Air Force in the 1971 War in low-level air combat) were sought to be removed in the process of designing the new aircraft. The first, repositioning of the air intake (no longer required to be so critically managed as that in the MiG-21 which was to operate at Mach-2 at 22-km altitude) to the side intakes to hopefully make the aircraft less susceptible to bird strikes which accounted for total loss of the aircraft in nearly a quarter of our flying accidents. The second was to install a better modern air interception radar with a head-up display in the nose now freed from the imperatives of the nose intake. Third, there would be space for a cockpit air-conditioning system as compared to the existing MiG-21 which instead has a cockpit heating system needed above 14/20km altitude. The bulk of our flying was being done at low level and the Air Force was expected to engage the enemy in air combat at very low altitudes and penetrate hostile air space at tree-top level. The MiG-21 cockpit temperatures in the north Indian summer would normally reach over 70 degrees Celsius within two minutes after take-off. Pilots would, on an average, lose as much as 3.5 kg weight in a 40-minutes low-level sortie (I proved it once in 1975) !

Third, the MiG-21 then was flying with 475 kg of ballast weight split into small pieces in most of the front fuselage to maintain the critical centre of gravity of a partially unstable aircraft design. The aircraft had a limited range and payload (like most Soviet aircraft of the 3rd generation in keeping with their defensive orientation) and their low cost allowed large numbers to be deployed defensively.

Hence, the penetration range of the aircraft in a ground attack role, or its time for air combat was limited. Utilising 475 kg for internal fuel would have dramatically enhanced its range as compared to the MiG-21.

Unfortunately, the decade of the 1980s was spent on one side in hyping the standard of preparation and Air Staff Requirements (ASR) to make it the dream of a fighter pilot! But someone forgot to increase the weight to accommodate everything that would make it a 21st century combat aircraft at par with the best in the world. On the other side, a vicious tussle raged as to who would head the new national project in or outside HAL? Ultimately, the proverbial Indian compromise was adopted and an ad-hoc organisation (more of it later) called the Aeronautics Development Agency (ADA) was set up as a registered society (to make financial management easier) but under the Defence Research and Development Organisation (DRDO) by milking HAL of designers and engineers. The critical point is that three decades after the design of the first and so far the only HAL designed multi-role combat aircraft, the HF-24 Marut, was commenced, the LCA finally started to move ahead with design feasibility that the IAF had major difficulties with. During those three decades, aviation technology had advanced exponentially and our early designers who formed part of the HF-24 design team, led by a German group under Dr. Kurt Tank, had retired. In the absence of institutional memory, the mistakes committed during the HF-24 were repeated in the LCA. In short, in 2013, the LCA has yet to reach its Initial Operational Capability (IOC) although the IAF has placed orders for 40 aircraft to demonstrate its commitment to the programme. And with a new engine, the GE 414, the aircraft would have to undergo significantly extensive development processes.

What lessons can be drawn from the above sketch? Some of the ones relevant to our present study can be briefly outlined as follows:

- Design and development form the critical foundation of indigenisation and self-reliance.
- The Design Division of HAL set up after independence has been emasculated over the decades. So much so, that the country is importing a basic trainer for *ab-initio* training from abroad after a lapse of four years.
- The final marginalisation of HAL's design and development capability was achieved by establishing the ADA under DRDO management, increasing the stakeholders and decision-authorities in the government and sidelining the IAF.
- The combat force level of the IAF is facing an unplanned 24 percent drop. It has happened when both our potential adversaries have pursued a massive modernisation of their air forces.
- What was true at the time of independence is true today. The Indian Air Force is the primary stakeholder in the aircraft and systems that it acquires and employs in defence of the country and its air warriors keep ready for the worst in peace and war.
- The Indian Air Force is expected to increase its force level to 42 combat squadrons by 2022 and possibly 49 squadrons by 2030 or so.

Pair of HAL HJT-16 Kiran Mk.IIs of the IAF's Surya Kiran formation aerobatic team at Aero India 2011.

HAL-assembled BAE Systems Hawk Mk.132 advanced jet trainer. (photo : Angad Singh)

If this is so, should not the IAF play greater role in the critical area in the processes of design, development and acquisition of the tools with which it has to function even at short notice perhaps against immense odds and yet win the wars of the nations? If the answer is yes, then the question is, how can that be achieved within the norms and parameters of Indian democracy?

Indian Navy Model The most simple and efficiently workable approach to indigenise design and development up to, and partly including, the manufacture of aircraft and weapons systems besides their integration with the platforms is to adopt the model that the Indian Navy has followed since independence. It needs understanding that this policy was inherited from the British since the Admiralty had directly controlled warship design and construction to meet their operational requirements over the centuries. Hence, the Naval HQ now has a Directorate of Naval Design under the Chief of Naval Staff (CNS) and also the Controller of Warship Construction which allows it

to direct the construction also. Most of the dockyards constructing and refitting warships are headed by naval officers. The third element is the WESEE (Weapons and Electronic System Engineering Establishment) notionally under the Ministry of Defence though managed under the Chief of Materiel in Naval HQ in close cooperation with the Scientific Adviser to the Defence Minister. It has highly qualified technical experts from the Navy and the scientific community on its strength. The Indian Navy's advanced capabilities in information warfare, cyber capabilities and warfare, etc. are all due to the enormous design and development work being carried out in WESEE. One possible reason for its success is that the electrical and electronic branch officers have very few vacancies at the top ranks; and WESEE provides professional challenges and satisfaction, besides the potential for employment in the corporate sector in later years. The IAF used to rely on a similar institution called the Directorate of Technical Development and Production (DTD&P). Two dedicated DRDO laboratories work in close cooperation with the Indian Navy beside a large number of qualified naval officers being assigned to a number of DRDO laboratories.

The key factor that emerges from a closer study of Indian naval warship design and construction strategy is that its four components outlined above function in deep harmony. The Ministry of Defence has been providing it full support for the past six decades. The success of the Indian Navy in indigenous design and development has been well recognised. The INS *Delhi,* a 7,000-odd ton destroyer which many in the international community interpreted to be a cruiser, was an instant success, when it was launched in 1997, and other *Delhi*-class ships have, if anything, surpassed its performance and capability. Many of the critical systems like guided missiles are still imported and integrated into Indian naval warships. It may be recalled that the Defence Minister, Shri A.K. Anthony had stated a couple of years ago that the Indian Navy from now on will not be importing any warships. The Chief of Naval Staff had recently stated that out of 44 warships under construction, 22 are being constructed in India. This indeed is a remarkable achievement, unparalleled by any other component of armed forces in India.

It is an example worth emulating by the IAF if it has to push for indigenisation of its aircraft and their support services without having to pay the price of depleted combat force levels and/or poor serviceability and sustainability of its aircraft due to poor product and spares support of even imported aircraft and those manufactured under licence. And the Ministry of Defence should support such a redirection. It needs to be clarified that the British relied totally on their private industry to design and develop aircraft of all varieties. At the government level, it was the Ministry of Supplies that dealt with the industry and placed orders on the industry on behalf of the Royal Air Force, with the UK Defence Ministry acting as the key organisation which also included the top hierarchy of the Air Force, what with a Minister of State heading the branch. When India became independent, the Ministry of Supplies was the agency to approve demands and approve acquisition.

But the Industrial Resolution of 1957 brought all defence activities and aircraft acquisitions under the Ministry of Defence which also separated itself from the Air Force leadership once the IAF and other armed forces became subordinate Services. But this also created a lacuna in that transport aircraft, airliners and general aviation remained in a limbo. In due course, the airliners were brought under the Civil Aviation Ministry, and military transport aircraft under the responsibility of Ministry of Defence in keeping with the Industrial Policy resolution. General aviation has remained in a limbo even now. The extensive review of the higher defence organisation triggered by the Kargil War provided only a weak, partial solution by changing the nomenclature without any reforms or reorganisation as such in terms-of creating an integrated Ministry of Defence. But that is a vast and different issue that need not be dealt with here although the organisation of the defence establishment and the place of the IAF in it are crucial issues that affect indigenisation.

HAL-designed HJT-36 intermediate jet trainer which is to supplant the Kiran in IAF service.

The IAF's fleet of MiG-29s is being upgraded to the UPG standard, the first 6 aircraft in Russia and the balance by the IAF at its base repair depot (BRD) at Nasik.

HAL-built Jaguar Maritime which are being upgraded to Darin III standards.

Design and Development Integral to IAF

The second option would be a variation of the Indian Navy's example to suit existing realities and the IAF's specific needs. Air Chief Mshl P.C. Lal had reorganised the Air Headquarters (HQ) in January after he took over as Chief of the Air Staff. If pursued as the directorate responsible for new projects, it had the organisational potential to become equal to the Naval HQ's Directorate of Naval Design. In essence, it separated many distinctly different issues under separate directorates. For example, -instead of the all-embracing Policy and Plans Directorate, he separated administrative plans from aircraft and weapons acquisition plans. What is of interest to our present study is that a Directorate of Projects was created under the Deputy Chief of the Air Staff. As the name suggests, this was to become the embryo for managing projects for the Air Force. Alongwith it, the Directorates of Systems Analyses to improve decision making, and of Air Staff Publications to produce the requisite literature were also established. The close coordination of the Directorate of Projects with the Directorate of Technical Development and Production (DTD&P), and the Scientific Adviser to the Chief of the Air Staff would have been the natural way forward. Unfortunately, this did not happen. So

Production of the Tejas LCA at HAL's Bangalore Complex has been protracted and is subject of major reviews by the Ministry of Defence.

much so, that when the Air Force decided to integrate and create a new weapons aiming and navigation system of the newly acquired Jaguar in 1979, the task was undertaken by an ad-hoc group of IAF personnel (with a test pilot as the key person) who created the Darin system that made the IAF Jaguars far superior to the British and French aircraft. The process is now producing the Darin III, the third development in the series.

Similarly, Air HQ has taken the initiative to indigenise as many line items as possible for the MiG-29 and the process is proving to be enormously successful. Our purpose in identifying these efforts and earlier organisations is to highlight the need and potential of establishing design and development of aircraft as an IAF responsibility with adequate interface with HAL management. Incidentally the old system of appointing Air Force officers as Chairman and General Managers is hardly conducive to the larger issue of indigenisation as the history of the past six decades shows.

As noted earlier, the ADA was established in the mid-1980s as an ad-hoc ad interim organisation with a specific task to design and develop the LCA with manpower seconded from HAL but with the organisation delinked from HAL as an independent registered society. Rationally, its original task has been long finished though the weakness in design (like the airframe being much heavier than the design stipulation) has not led to its performance meeting the ASR against which the LCA was finally approved for design and development. Since it was done under the initiative of the DRDO, the head of DRDO continues to be the Chairman of the society and, thus, the head of the ADA. DRDO designed the aircraft, but had to go to HAL for producing the product. In spite of excellent cooperation between the ADA (read DRDO) and HAL, there have been serious problems in productionising the design. Historically (and I can cite many examples), this was to be expected and logically ADA should have been merged with the HAL design bureau once the technology demonstrator was ready.

In fact, ADA failed to even start a follow-on design project in the early 1990s which could have begun to mature by now. I had argued in favour of doing so at the LCA progress review attended by the then Defence Minister, Shri Sharad Pawar, in late 1991. This may be fairly accurately ascribed to its one-shot task and goal of designing the LCA and it had no stake in becoming the design and development hub for all or at least some of the IAF aircraft needs. Nor did DRDO, the controlling authority of the ADA, appear to have looked at it from that perspective. It had made progress in many areas of design and development of aircraft; and a great deal of the research work had been outsourced to nearly 300 academic institutions. There is no reason why it could not have undertaken at least the design and development of a primary trainer which, it was clear at that time, the IAF would require badly after the HPT-32 had been in service for around 15 years.

The best course in the interest of the country even at this stage is to bring the ADA under the Air HQ as its design and development capability. DRDO can then concentrate on strategic systems like long-range highly accurate ballistic missiles (hence, usable with conventional warheads), manoeuvrable reentry warhead/vehicle (which has been operationalised by the US, Russia and China already), and Ballistic Missile Defence (BMO) (especially with boost-phase interception), which may have a long gestation period, and withdraw from areas like design of an odd aircraft. In order to optimise the output of the ADA, probably on Air Marshal at the top (possibly a second Deputy Chief of the Air Staff) may have to be nominated for this role; and this, in the era of the A.V. Singh Committee implementation when the Air Force is looking for suitable jobs for the authorised strength of Air Marshals would serve the dual purpose of taking on key tasks within the existing force level. There are many highly capable technical officers and test pilots in service who could usefully take on the responsibilities of managing the ADA. The other alternatives would be substantive expansion of the ADA to undertake all design and development tasks in the aviation sector or at least take on the responsibility for future IAF needs rather than continuing the ad-hoc programmes. In addition, some coordinating mechanism has to be evolved between the ADA and HAL so that design-to-production synergy can be built up. In conclusion, one can assert that the best course of action is to follow the known experience of the Indian Navy and bring the ADA under the IAF to form the critical design and development agency for future aircraft and systems. If, for some reasons, the ADA cannot be brought under the IAF which is the primary stakeholder for military aircraft, then logically, the ADA could be merged with HAL. Leaving the ADA as an interim ad-hoc institution for decades in such a critical area would be a gross mistake.

Research and Development

Two issues demand serious attention. The first is that a Research and Development (R&D) laboratory is required to be established in the Air Force to undertake a variety of tasks like new weapons and system integration, etc. It is worth noting that the US Air Force (USAF) has a number of its own laboratories for R&D for new capabilities in the aerospace domain. And they compete with each

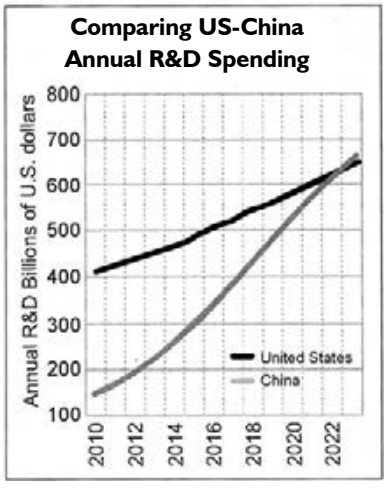
Share of Global R & D Spending			
	2010	2011	2012
US	32.80%	32.0%	31.1%
Asia	34.3%	35.5%	36.7%
Japan	11.8%	11.4%	11.2%
China	12.0%	13.1%	14.2%
India	2.6%	2.8%	2.9%
Europe	24.8%	24.5%	24.1%
Rest of the World	3.0%	3.1%	3.2%

Source : "2012 Global R&D Funding Forecast", Battelle R&D Magazine, December 2011.

other to ensure that the USAF remains the world leader in aerospace technology. One has only to look at their programmes to understand how and why the US is far ahead of even highly industrialised Western countries, and the USAF remains the preeminent air force in the world.

Aircraft design and development is deeply linked to the R&D expenditure in the aerospace sector specifically and national R&D investment in general. Hence, looking beyond the aircraft industry and design and development issues in enhancing indigenisation, the second major issue that deserves attention is that Indian expenditure on R&D is pathetically low for a country that is already at the cusp of being a major power. Over the past three decades, the total R&D as a percentage of national Gross Domestic Product (GDP) has not exceeded 0.8 percent; and out of this, nearly 0.7 percent is spent in the government agencies like DRDO and Department of Science of Technology in its laboratories. There is a serious risk if we do not take remedial measures; industrial production, already on the decline, may further go down in the coming years and the great Indian dream may come to nought. In that case, there could be serious domestic violence adding to the problems of economic growth.

According to *Battelle R&D Magazine,* global R&D spending was expected to grow by about 5.2 percent to more than $1.4 trillion in 2012. Most of the global funding growth is being driven by the Asian countries, which were expected to increase nearly 9 percent in 2012. The share of global spending on R&D explains



clearly how some countries like Japan and China have advanced so much (see Table 1 for details). While the US, spending almost a third of the global R&D expenditure, is obvious as the largest spender, this also has to be seen in the context of the United States' economy and, more important, the advances in technology that have been funded for over a century. At the same time, the major driving force for US R&D funding at such high levels is that the country clearly wants to stay ahead in technology compared to any other country though some day, another country may close the technological gap. But only a large country like China may be a real challenge some day as a peer.

As may be seen from Table 1, India is one of the very low spenders on R&D. China has been spending an average of 13 percent of the global expenditure on R&D and the results are clear in terms of the technological advances supporting economic growth in an interactive process. China spends nearly 13 percent of the global R&D expenditure whereas India accounts for a mere 2.8 percent or so, during the three years under review in spite of the fact that its average annual GDP growth for the first decade of this century was in the order of 8.4 percent! This may well be the reason why the industrial growth (as a percentage of GDP) has been slowing down in recent years since it obviously depends heavily upon licensed production (as in the case of the aircraft industry) rather than innovation through research and development even if it is only a case of reverse engineering, like China does in many cases. At the rate China is investing in R&D (besides US offshore R&D operations in China), it is likely to surpass US R&D spending by 2023 (See Fig 1).

Note: China's double digit growth in R&D spending is expected to match and surpass that of the US by about 2023, if several forecasting criteria are maintained. This forecast is based on Chinese R&D continuing at an average 11.5 percent per year and US R&D growth averaging about 4.0 percent per year for the next 13 years. Present US R&D annual growth is only about 2.1 percent but has been more than 6 percent over the past six years. China's R&D growth over the past 15 years has consistently exceeded 10 percent.

What is perhaps more relevant is that China's rate of growth of R&D spending has far exceeded its national GDP growth rates over the past two decades or so. In 2011, China's Ministry of Finance had announced its allocation of$125 million to promote the application of China's R&D results into the commercial sector with the aim of accelerating the transfer of science and technology achievements into production and promoting corporate technology innovation-steps crucial to competitive industrial production growth. Secondly, unlike India, where nearly 0.6 percent of the GDP on R&D is from government funding, and the balance amounting to only 0.2 percent of the GDP is spent by the business/private sector, in China's case, the reverse is the norm, the general impression of state run institutions being the norm notwithstanding.

The post-1991 growth in India's economy has been remarkable and averages around 8.4 percent for the first decade of the new century. The service sector has shown the highest growth rate among the three segments of industrial production, agriculture and service sector. With the economic meltdown since 2008, it was inevitable that Indian economic growth would also slow down although it has remained one of the two major countries (China and India) with a fairly high economic growth. Even industrial growth has been fairly high. This is no doubt due to Foreign Direct Investment (FDI) which has brought with it the knowledge and means of industrial *production* and not necessarily any meaningful investments in R&D for future growth in India. A RAND study had looked at the composition of national gross expenditure on R&D in different countries over a period of ten years average from 1995 to 2005 (see Table 2). The expenditure has also been depicted in sectorwise distribution.

What strikes one is that India is the only country among those examined where the industry's contribution to R&D is significantly lower than that of the government. Obviously, the reforms have not touched the core activity for future industrialisation and stares at the reader as the weakness in the industrial revolution that India must pursue if it has to sustain its growth rate over the coming decades. It is regrettable that the industry's

contribution and investment on R&D has remained poor.

Such low investment in national R&D by the industrial sector runs contrary to the expectation that the private sector should/would get involved in the aerospace industry. The government needs to look into this fundamental lopsided weakness.

As may be seen, in the United States, which stands as a model of technology driven economic development, the private industry's investment in national R&D is over six times that by the government. In India, a handful of industries like the pharmaceutical industry have invested substantially in R&D after 2000 and their growth has been remarkable as a consequence of this approach. It appears that the early successes of some of the government initiatives in nurturing new biotech companies are responsible for this change in the scenario. But, this has not happened in the other sectors. This stands as a powerful reason for the IAF to get involved in R&D in the aerospace sector like the US Air Force relying on a number of laboratories under it often in competitive programmes between the laboratories such as the hyper velocity vehicles for the future as part of the USAF programme of Prompt Global Strike [as distinct from the Defence Advanced Research Projects Agency (DARPA) which undertakes R&D for the Department of Defence].

In conclusion, one has to reemphasise that design and development is the critical foundation of the aircraft industry and, hence, every step taken toward self-reliance through indigenisation must give it the greatest emphasis. This is where India has been remiss. The Indian Air Force has the greatest and most crucial stake in this process and possesses the capabilities to undertake the tasks with minimal reorientation. The ADA should be brought under Air HQ to begin moving toward the Indian Navy model of design, development and manufacture. This model has proved its value over six decades and

National Gross Expenditure in R&D (GERD) (Average from 1995 to 2005 as a percentage of GDP				
	USA	CHINA	INDIA	
GERD	2.6	1.0	0.8	Gross Expenditure in R&D
GOVERD	0.3	0.3	0.6	Government Expenditure in R&D
BERD	1.9	0.6	0.2	Business Expenditure in R&D
OTHERS	0.4	0.1	0.0	

Source : RAND Report, *China and India, 2025 (Santa Monica : RAND, 2011)*

INS Satpura (lead), is one of the Navy's Shivalik-class stealth frigates designed by the Directorate of Naval Design and built by Mazagaon Dockyards.

The Indigenous Aircraft Carrier-1 to be commissioned as INS Vikrant, was launched at Cochin on 12 August 2013.

now stands at the cusp of self reliance in meeting the future needs of the Indian Navy, even designing and building India's first aircraft carrier at the Cochin Shipyard. The nuclear submarine, no doubt, took quite some time as should have been expected; but the sea trials of the INS *Arihant* are scheduled in the near future. The earlier the government agrees to transfer the ADA to the IAF, the earlier we would put our aircraft industry on a sound footing for the future and move away from ad-hoc experimentation which had led us into the present cul de sac.

The second aspect of design and development is that designers are unique in their education but more so in their conceptual abilities. Hence, they deserve to be handled and utilised differently. The Soviet Union, in fact, went all out to do so: its aircraft were known by the names of their designers and the designers occupied the place of the head of the aircraft manufacturing facilities of that enterprise. We have tended to marginalise not only design and development but also our designers. Scientists from institutions like the National Aerospace Laboratories (NAL) in India would perhaps be the best heads of the Design Division of HAL or even as Chairman, HAL. Curiously, Dr. Valluri, who headed NAL and Raj Mahendra who for a long time had headed HAL's design bureau Dr. Valluri and who was keen to involve, were finally sidelined when the ADA was established; and so was (later) Air Mshl P Ramachandran, an outstanding test pilot, operational fighter pilot and one of the finest officers that the IAF had, who was the key person in developing the Darin weapon aiming and navigation system for the Jaguar in the early 1980s. Personalities matter when national programmes are to be carried out. But we made another mistake: waiting for the LCA and not seeking an alternate operational aircraft for the IAF which simply led to unplanned decline of the combat force level, seriously jeopardising national security.

Looking ahead, the offsets clause offers a unique opportunity to find foreign investments as well as the relevant technology from the prime manufacturers, provided we handle it correctly. The first issue is that offsets must not be seen as a source of FDI only. They must be viewed as the route to enhance the technological capacity of the country and, hence, expedite the ongoing industrial revolution. Second, all the aircraft and syste91s that we have bought or are likely to buy (which are not joint ventures) have already been designed. Hence, little design technologies can be accessed as such. But all such aircraft have a life of 30-40 years during which they will require technological upgrades almost every decade.

The offsets should be geared to undertake such tasks and, hence, enable design and development in R&D establishments, preferably in the private sector, with collaboration with the prime manufacturer which should employ increasing numbers of Indian scientists and designers to work on the system engineering and upgrades. This process should create the requisite design and development capabilities in India in less than one generation besides supporting the larger national techno-economic base. It may look impossible but the steps like those of the Chinese Finance Ministry referred to above should become the norm. Above all, we need to enhance the investment in national R&D efforts, especially in the private sector, facilitated by the government but not directed by it.

✻ *This is lead chapter in the book '**Indian Air Force : The Case for Indigenisation'**, published in 2013 by the Centre for Air Power Studies, New Delhi, edited by Air Commodore Jasjit Singh, AVSM, VrC, VM*